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February 2004

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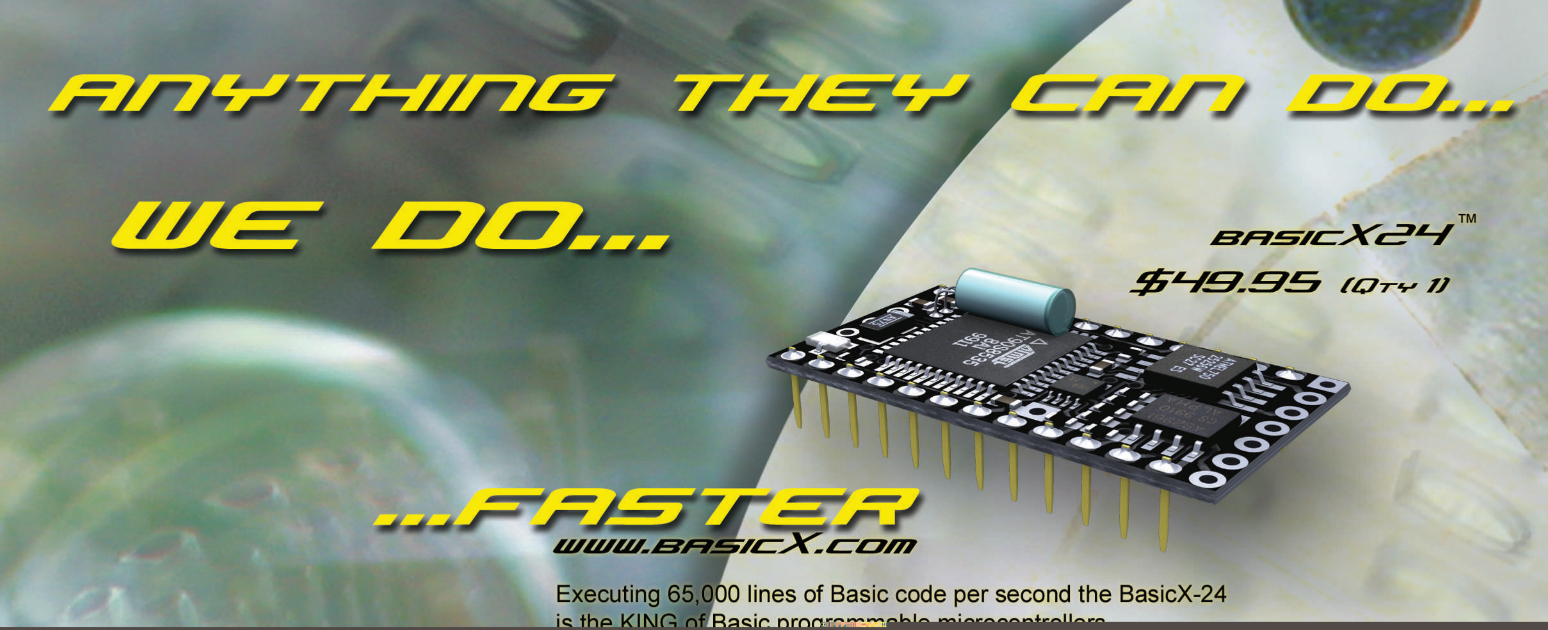
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Dear Nuts & Volts:

I read your magazine from cover to cover and find it very stimulating and informative. It helps me keep up my skills in the electronics field.

However, I noticed an error in Ray Marston's "Bipolar Transistor Cookbook" feature (November 2003). In the last paragraph of the section titled "L-C Oscillators," on page 70, the formula for determining resonant frequency is given as "f=1/2LC". This is incorrect and should be "1/2 Pi sqr(LC)".

Tim Leon, CET
Vacaville, CA

Good catch, Tim. That was our mistake, not Ray's. — Editor Dan

Dear Nuts & Volts:

I really enjoyed the article, "The New Electronics Experimenter," by Louis Frenzel, in the January 2004 issue. He really hit the nail on the head in describing today's electronics experimenter. I'm 63 years old and have been down most of the paths he discussed, including building Heath kits, computer kits, projects in *Popular Electronics*, *QST*, and *Radio Electronics.* I also went through the various Heath Kit Education home study courses, from DC electronics to digital electronics and microprocessors to the BASIC Stamp. I have dabbled in audio, short wave radio, scanners, RC models, personal computers, digital video and cameras, auto electronics, and even built radio telemetry equipment for tracking wildlife.

I work in natural resources, but my true love has always been electronics. I am looking forward to learning more from *Nuts & Volts* and *SERVO Magazine* and to having more time to spend with my hobby when I retire in two years. Keep up the good work. Thanks.

James (Jeb) Stuart
Anchorage, AK

Dear Nuts & Volts:

I enjoy the magazine as one of the few remaining periodicals designed for the electronics hobbyist in the US. In an age of disposable consumer electronics, it's good to see quality materials and projects. Thank you.

If I may, I have some quick comments on several points of D. Prabakaran's, "'All About GPS"' article:

Location: The proper term for GPS location determination is trilateration, not triangulation. Triangulation involves angles in determining a solution, where trilateration (GPS) does not.

Frequencies: Currently only L1 and L2 are broadcast .

GPSPower: GPS broadcasts L1 @ 380 watts and L2 @ 80 watts.

Receiver Sensitivity: Receiver sensitivity is around -130 to -140 dBm, depending on manufacturer and configuration.

Selective Availability: SA was turned off, via presidential order, on May 1, 2000. The proliferation of GPS devices and location-based services that have since spawned preclude the government from ever turning it back on.

DOPS: There are many more DOPS than just HDOP (Horizontal Dilution of Precession). The other common ones are VDOP (Vertical), PDOP (Point), TDOP (Time), and GDOP (General.) These are all unitless numbers that reflect the relative precision of the particular DOP. Different GPS manufacturers display this information differently.

Thanks again for a great publication!

Thomas Homan
via Internet

Dear Nuts & Volts:

I received my January 2004 issue of *Nuts & Volts* last Saturday. I guess the PO had a bunch of stuff to get out of there and just delivered it early. No problem for me! I do enjoy the magazine, and really appreciate the smaller size, compared to the issues a few years ago, since they store more readily. I keep good magazines like that and still have the very first issues of *QST* that I purchased just before WWII.

I am a multi-hobbyist. I received my ham license in 1948, and rose to Chief Electronic Technician in the USN. I taught electronic servicing to the maintenance crew for the toll equipment on the Kansas Turnpike Authority when they changed over from card hole punch type machines with stepper motor accounting to modern computers (which used Motorola 6800 type computer chips at the time!). I retired nine years ago, yesterday, after 37 years with the KS Turnpike, where I had been head of the Communications Department.

I appreciate *Nuts & Volts* as a magazine for experimenters like few or no others. It seems like so many people want to have everything engineered and they just buy it without getting their hands dirty, so the field of new information has shrunk badly.

A year ago, I designed and built a prototype for a home siren device, interfacing with a paging receiver to alert people in an area not well served by community sirens. The folks who had me do that have been short on cash to promote it, so I don't believe it will go very far. They do have a patent on the design idea.

Keep up the good work. I do enjoy the magazine very much.

Carl Fisher
Augusta, KS

Dear Nuts & Volts:

I easily identified myself as a member of a dying breed in Louis Frenzel's article, "The New Electronics Experimenter," January 2004 *Nuts & Volts*. For some time, I have been

Continued on Page 85

by J. Shuman

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FOUNDER/ASSOCIATE PUBLISHER
Jack Lemieux

PUBLISHER
Larry Lemieux
publisher@nutsvolts.com

ASSOCIATE PUBLISHER/ VP OF SALES/MARKETING
Robin Lemieux
display@nutsvolts.com

MANAGING/TECHNICAL EDITOR
Dan Danknick
dan@nutsvolts.com

EDITORIAL ASSISTANT
Alexandra Lindstrom

CONTRIBUTING EDITORS
Forrest Mims, Mike Keesling, Jon Williams, Louis Frenzel, Jeff Eckert, Ray Marston, TJ Byers, R.B. Whittingham, Dan Shanefield, L. Paul Verhage, Schlomo Engelberg, Gerard Fonte, Ralph Lorenz, Mark Balch

CIRCULATION DIRECTOR
Mary Gamar
subscribe@nutsvolts.com

SHOW COORDINATOR
Audrey Lemieux

WEB CONTENT/NV STORE
Michael Kaudze
michael@nutsvolts.com

PRODUCTION/GRAPHICS
Rosa Gutierrez
Shannon Lemieux

DATA ENTRY
Karla Thompson
Dixie Moshy

Electronics Q&A

In this column, I answer questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist.

Feel free to participate with your questions, as well as comments and suggestions.

You can reach me at: **TJBYERS@aol.com**.

What's Up:

The usual assortment of requested circuits. My favorites are the soldering iron warm down and low-battery indicator. Discovered a new reader hobby, and spent a lot of ink on an emerging technology. Another reader comes through with a tip, and there are many Cool Websites! to check out.

Good-bye 12 V, Hello 42 V

Q. How about some details (or an appropriate website) about the upcoming change in automotive electrical systems? I read somewhere that the new bus voltage will be 42 volts. Is that 20 cells times 2.15 volts per cell? What other interesting and unique features will be implemented? Will something like PCM be used for switching appliances (lights, blower, rear-window heater, etc.)? Any information or clues that you could pass along would be very interesting and most appreciated.

Joseph F. Richmond
via Internet

A. The new 42-volt automotive electrical system comes as a result of ever-increasing power demands. Back in the days of old, way before many of you were born, six volts was the standard power bus for autos. That's because the cars in those days had almost no electrical demands — typically head/tail lighting and maybe a heater motor. Somewhere in the mid 1950s, the ante was upped to 12 volts. This came as a result of a demand for air conditioning, brighter headlights, and higher-compression engines (which needed bigger starter motors).

Today's cars really put a demand on the electrical system with power windows/seats, climate control, monster stereos, and window defrosters — not to mention of what's up and coming: GPS, communications, PCs, on-board video, etc. It's no wonder the 12-volt bus is feeling the strain. It's estimated that, by the year 2010, some cars will require 10 KW of power! That's enough to power a home. To meet these demands, the voltage has to increase. Why?

Because Ohm's Law says so. Let's say you have a six-volt system with a 10-amp load (60 VA) connected by a 0.1-ohm wire. Ohm's Law says the voltage loss across the wiring is one volt, making just five volts (50 VA) available to the load — a loss of 17%. If we up the voltage to 12 volts and reduce the current to

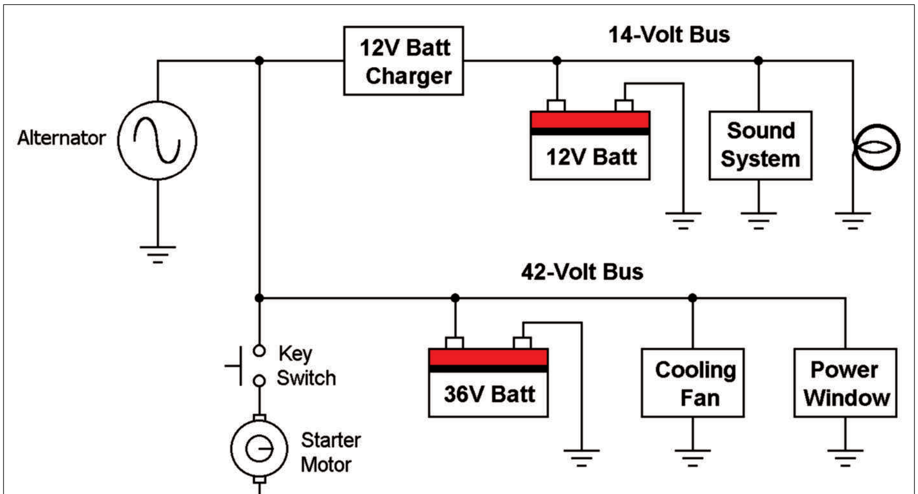


Figure 1 Typical 42-Volt Hybrid System

five amps (60 VA) running through the same 0.1 ohms, the loss is now 0.5 volts — 11.5 volts to the load (57.5 VA). Quite an improvement. Applying the same analysis to 36 volts (a.k.a., 42 volts) gives us 35.98 volts (59.9 VA) to the load.

The first 42-volt systems will be hybrids: a mixture of 12 volts and 42 volts (Figure 1). The 42-volt system is actually based on a 36-volt battery, but it's called 42 volts because it takes 42 volts to charge a 36-volt battery. This is much like today's systems, which operate at 14 volts but use a 12-volt battery. The alternator will output 42 volts for charging the 36-volt battery. A 14-volt battery charger, based on DC/DC technology, will keep the 12-volt battery fresh.

For the moment, these controls will be separate (42-volt headlamps are a ways off), but eventually, they'll merge into a single 42-volt bus. The reason for choosing 42 volts over a higher voltage is the 50-volt barrier, which is considered the highest voltage that is safe to work around without special precautions.

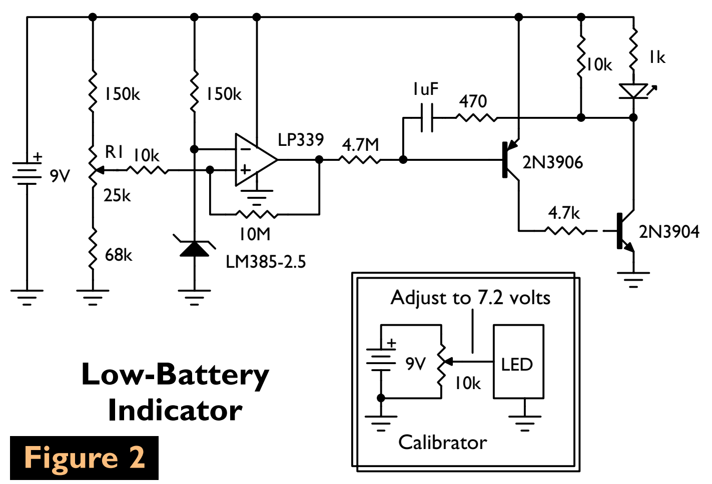
As for the immediate advantages:

- Wiring harnesses will be thinner and lighter in weight.
- Connectors will have less loss.
- Window motors will be smaller and more efficient.
- Electric fans will replace pulley-driven radiator fans.

For more details and features, check out the following websites:

Assembly Magazine
www.assemblymag.com/CDA/ArticleInformation/coverstory/BNPCoverStoryItem/0,6490,98697,00.html

Auto Speed
www.autospeed.co.nz/cms/A_0319/article.html



Low-Battery Indicator

Figure 2

CMC Power Systems
www.cmcpower.com/html/electricity/why42volt.asp

Canadian Driver
www.canadiandriver.com/articles/jk/at_010515.htm

SAE
www.sae.org/42volt

Low-Battery Indicator

Q. I have an electric guitar that uses active pickups powered by a nine-volt battery. I'm looking for a simple circuit that would live inside the guitar and tell me at a glance if the battery is still good. I imagine an LED that turns yellow when the voltage drops to five or six volts, otherwise the LED does not light. Do you have any suggestions?

David Walker
via Internet

A. How about a blinking LED? The circuit in Figure 2 monitors the voltage of the nine-volt battery, and flashes the LED every two seconds when the voltage falls below 7.2 volts (the voltage most manufacturers consider the end of battery life). The circuit draws a mere 120 microamps, which is just slightly more than the self-discharge current of the same battery sitting on a shelf. To calibrate the monitor, connect it to a 7.2-volt source (see insert) and slowly adjust R1 until the LED starts to blink.

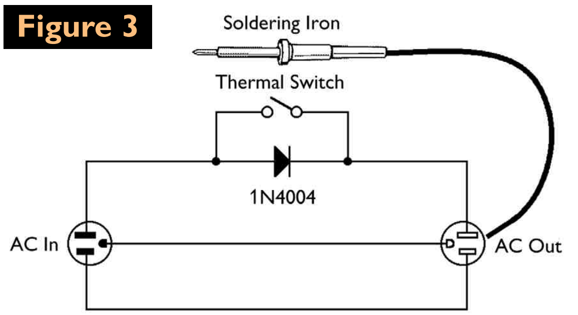
Iron Keeps its Cool

Q. Most of us in the shop work with an 80 W solder iron and would like to control its temperature in order to prolong the tip and iron life by preventing overheating. Can you please provide a simple yet effective diagram for a solder iron heat control device with a 120 VAC socket? This would also make a great project for beginners in electronics!

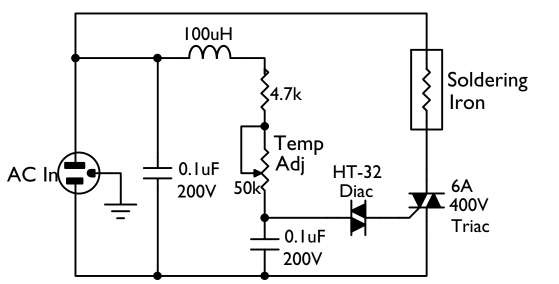
D. Zillbermann
via Internet

A. If you're talking about turning down the heat when the soldering iron is in the holder, then turning it back up when it's removed, the circuit in Figure 3 is what you want. This design simply inserts a diode into the AC line to reduce the average voltage to the iron. The thermal switch (available from All Electronics, 800-826-5432, **www.allelectronics.com** — catalog THSW-70) is positioned so that it opens when in proximity to the soldering iron with the iron in its holder. The heat from the soldering iron causes the switch to open and reduce the AC Out voltage. When the iron is

Figure 3



Soldering Iron Tip Saver



Soldering Iron Temp. Controller **Figure 4**

removed, the switch closes, shorting out the diode, and applies full power to the soldering iron.

If you're looking for a variable temperature controller for the soldering iron and want to keep it simple, check out the circuit in Figure 4. This is your run-of-the-mill triac dimmer that's been reduced to the minimum number of parts. The temperature is controlled by varying the phase angle of the sine wave, creating a "dimming" effect just like in a light bulb. The limitation is that you can only guess at the temperature (or measure it and calibrate the dial) because there is no temperature sensor to control a feedback loop, as would be the case with a true thermostatic controller.

Calibrate! Calibrate! Dance to the Music

Q. The capacitance meter circuit in your July 2003 article is something I'm very much interested in. However, I don't understand how to determine the value of the capacitor being checked.

John
Cohoes, NY

A. All test equipment, whether homemade or commercial, has to be calibrated. In the capacitance meter described in the July column ("Simple Capacitance Meter"), this is done by inserting a 1.0 uF capacitor across Cx, and adjusting the 5 k pot until the 0-1 mA meter reads full scale with the selector switch in the S2 position. The scale is linear, which means that a 0.5 uF cap will read mid-way on the scale, or 0.5 mA. A 0.1 uF cap will read 0.1 mA, and so forth.

The accuracy of the meter changes as you switch from one range to another and depends on the accuracy of the timing resistor, R. If you use 5% resistors, then expect to have as much as a 5% error when you switch ranges. Using 1% resistors improves the accuracy.

Tolerance Makes Cents

Q. I have a question about the meaning of parts specifications. Let's say you buy 36-volt zener diodes at 5% tolerance. Does it mean that three-sigma from 36 volts is 5% and that all the parts bought will fall within that tolerance? I'm looking to see what the sigma is so as to properly tune the design.

Fred Sprague
via Internet

A. Electronic components are rated on a fixed deviation of plus and minus a fixed value, not three-sigma (which is a mathematical deviation curve). For example, a 36-volt zener diode with a 5% tolerance means that the voltage of the zener is guaranteed to be ±1.8 volts of the standard value; in your example, the zener voltage is in the range of 34.2 to 37.8 volts. The actual values tend to cluster by the batch run, with one batch having a peak around one value and another batch centering around a different value. Temperature also affects the voltage of a zener, which is why the tolerance is always rated at a specific temperature. Typical temperature ranges are 0° C to +70° C (commercial) and -55° C to +125° C (military).

Tolerance is not an indication of poor manufacturing. Closer tolerances can be achieved, but at greater expense. A zener (or resistor) with a 10% percent tolerance costs less to produce than one with a 5% tolerance.

Power Supply Design 101

Q. Is there a formula to determine the size of the output filter capacitor in a DC power supply? I find many different sizes in different DC power sources, and would like to

know what determines their size.

Ted Asousa
via Internet

A. The simple answer is: capacitance is used to reduce the amount of ripple voltage that is ever present on a DC power supply output. Unfortunately, the formula isn't as simple, but I think I've at least made it less math intensive. Here is the simplified equation:

$C = [(I_{LOAD} \times t)/P\text{-}P_{RIPPLE}] \times 10^6$

where

I_{LOAD} = the DC output current; it is calculated using $I_{LOAD} = E_{OUT}/R_{LOAD}$

$P\text{-}P_{RIPPLE}$ = the acceptable peak-to-peak DC output ripple voltage

So far, so good. Now comes *t*, which is the hard part because it depends on the rectification method used and the line frequency. The capacitor requirements are less strict if you use full-wave rectification (Figure 5).

$t = 1/(2 \times \text{line frequency})$; $t = 0.0083$ for 60 Hz and 0.01 for 50 Hz

How about an example? Let's design for five volts out at one amp, with 100-mV peak-to-peak ripple, running from a 60-Hz wall-wart. Plugging these values into the equation nets a capacitance value of 8300 uF. An off-the-shelf 10,000uF cap will work perfectly.

$C = [(1A \times .0083)/0.1V] \times 10^6$
$C = [.0083/0.1] \times 10^6$
$C = [.083] \times 10^6 = 8300uF$

Sink the Bismark!

Q. I spend many of my weekends sinking ships — really! The hobby is called R/C Warship Combat, and it is heavly into electronics for just about every aspect of the sport. One of the tools of the trade is a bilge pump that pumps water out of the hull to keep the ship afloat after battle damage by pumping water out of the hull. I've been playing with a circuit built around a TIP120 transistor and a relay to start the pump when water is detected. The problem I have with it right now is that it works in most lakes, but not all. I'm guessing this is due to lower mineral content or salinity. I would be most interested in a simple circuit that would be more reliable, but still compact enough to fit in very confined spaces.

Charley Stephens
Battlers Connection

A. I looked over the circuit you sent and can tell you that your connection of the level sensor to the collector of the TIP120 (Figure 6) reduces the detector's sensitivity. Think about it: you're using the transistor as an on/off switch. The sensors are used to provide base current to the transistor to turn the switch on, but when the transistor switch turns on, the top sensor no longer has any voltage to apply to the base, which causes the transistor to turn off.

The answer is to connect the sensor to the +6 volt source through a 10 k resistor. This way, the base current isn't dependent on the transistor's collector voltage, only the conductivity of the lake water, which makes the sensor more sensitive. (If the sensor appears too sensitive, increase the size of the resistor.) I also swapped the TIP120 for a smaller MPSA14 unit and recommend you use a compact reed relay, like the RadioShack 275-232 (don't worry that it's rated five volts; relays are current, not voltage operated, so no will be damage done).

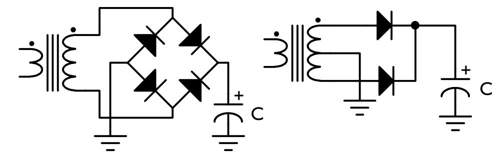


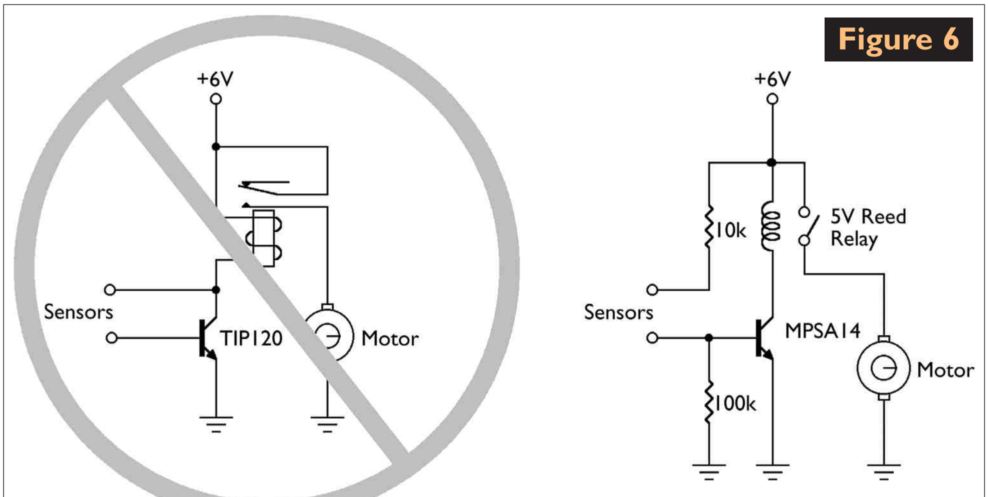
Figure 5 Full-Wave Rectifier

Inverter Waveform

Q. I am curious about your thoughts on using modified sine wave inverters with switching power supplies, like those used in PC computers. I've looked at the waveform on a scope, and noticed a big rush of current at the step from 0 to 170 volts that decays exponentially. With a true sine wave, the current influx is less sharp at the beginning, and the whole thing looks like a rectified half-wave. I'm using a Tripp-Lite modified sine-wave inverter on my old computers with no apparent harm, but would appreciate an expert opinion.

John M. Buzby
Boston, MA

Figure 6



Warship Battle Pump Sensor

A. I'm no expert, but I can tell you the reason for the different current profiles between the two waveforms. Off-line switching power supplies have a capacitor input (see "Power Supply Design 101" above). Capacitors charge exponentially, with a heavy beginning current that tapers off as time increases. If the applied voltage is gradually applied, as is the case of a sine wave, the inrush current is tempered. The modified sine wave (Figure 7), on the other hand, causes sudden current surges with each step.

Is it damaging? Not likely. Most of the stress is with the input rectifying diodes, which have to take the brunt of the current surge. Fortunately, diodes have a greater surge rating than they do an average current value and the surges are relatively small and short with a stepped waveform. So unless you are using a power supply that's marginally functional, I say go ahead and use a modified sine wave inverter. Now, want me to comment on those cheap, square-wave inverters?

Modified Sine Wave

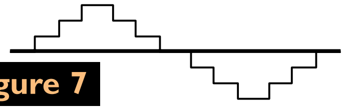


Figure 7

Portable Cat 5 Cable Tester

Q. I saw your circuits for testing Cat 5 cables, but I was looking for a circuit that will do a wire map for cables that are already installed in the walls. The first use is to check for proper pinouts and the second is to locate breaks or no contacts at the jack. I want something small, portable, and inexpensive; the tester I have is the size of a suitcase.

Doug Mooney
via Internet

Q. I need to check the continuity of a custom-made cable with a DB25 connector that uses pins 2 through 8 and pin 20. Basically, it's a Cat 5 cable, with twisted pairs and a custom connector. The cable is moved around a lot, and after several moves, the stiff wires shear at the crimp-pins.

Although I'm in the process of replacing these stiff wires with something more flexible, I need to find a fast way to check out the pinouts for the cables that are in service and verify those to be placed in service. I would like it to be compact (pocket size), battery operated, and have LEDs to boot.

Ifostano
via Internet

A. The schematic in Figure 8 is an adaptation of a commercial Cat 5 cable tester. A 4017 sequences the testing of the pins using LED indicators. Each Transmitter LED lights in order and should correspond to its related LED at the Receiver. If the Receiver LED doesn't light, the pin is open. If more than one Receiver LED lights, the wire is shorted. If the LED lights, but doesn't correspond to its partner, the pins are exchanged. The LEDs are sequenced by pressing the Press To Select pushbutton.

If you wish, you can automatically sequence the LEDs using a 555 timer (see Auto Select insert). This allows you to connect the Transmitter in one room and monitor the sequence with the receiver in another room.

Reader Tip

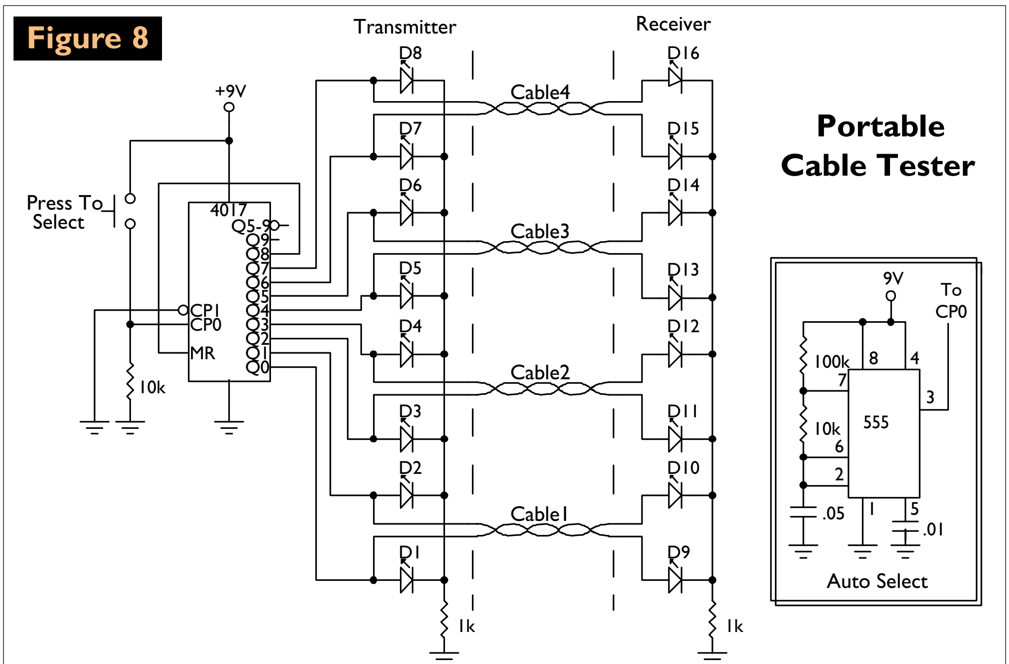
Here's a lamp delay circuit (Figure 9) I developed awhile back that is simpler than the one you printed in the Nov. 2003 issue. I have both a bipolar and MOSFET design. Here are some notes about the circuit:

1. R1 is optional and limits the charging current to protect the car door switch from arcing damage. It is probably also beneficial to limit the charging current through the capacitor.

2. The energy for running the light an extra 15 seconds is stored in the capacitor, C1.

3. The capacitor discharge time-constant should be approximately C1 * (R1+R2).

4. A diode should not be needed across the relay contacts since the turn off of the 2N3906 will be slow and gradual, instead of a sudden switch off.



5. Almost all of the bulb current will be carried by the relay, so the additional IN4001 diode should not reduce bulb brightness and can be eliminated if you trust the relay contacts.

Wayne
via Internet

MAILBAG

Dear TJ,

I have just read the question about ferroresonant transformers in the Dec. 2003 issue and wish to add that Sola also supplies ferroresonant transformers that are "Harmonically Neutralized" to minimize the impact of the third harmonics on the waveform. This technology requires that part of the capacitor winding be separated from the rest of the capacitor winding by a set of silicon steel shunts. This additional winding comprises approximately one-third of the total capacitor winding. A visual inspection will reveal three coils, separated by two sets of shunts.

The output waveform looks pretty close to a sine wave, with none of the flattening out that you mentioned. I have measured harmonic distortion values in the range of 1.5%-3.0%, which is not bad for ancient technology. However, I have noticed some "clipping or apparent commutating" distortion when using dynamic loads, such as switch-mode power supplies. Even this distortion does not seem to be catastrophic.

Another potential problem for ferroresonants is that they can be audibly noisy, so sitting in the same room as one can become irritating.

Dick Clarke
Total Recoil Magnetics

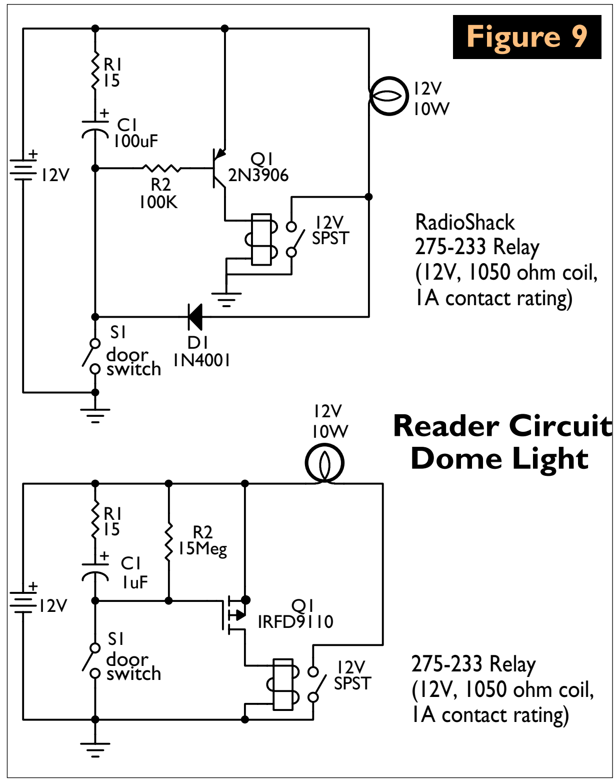
Dear TJ,

In the December issue's schematic for a +5 to -5 converter (Figure 10), is the 10 uF cap between -5 volts out and ground reversed — or am I missing something?

Jim Balderrama
via Internet

No, I missed it when I drew the schematic. Good catch!

TJ Byers
Q & A Editor



Dear TJ,

Your articles are usually accurate and informative. However, in the December 2003 issue, page 24, you state that the circuit illustrated in Figure 5 features a bandpass filter, of which you show the frequency response in Figure 6. In fact, the network composed of the series 100-ohm resistor and 1-uF capacitor to ground, at pin 3 of the second 555, is a low-pass filter which, as you correctly state, attenuates the off harmonics.

André Kesteloot
via Internet

Cool Websites!

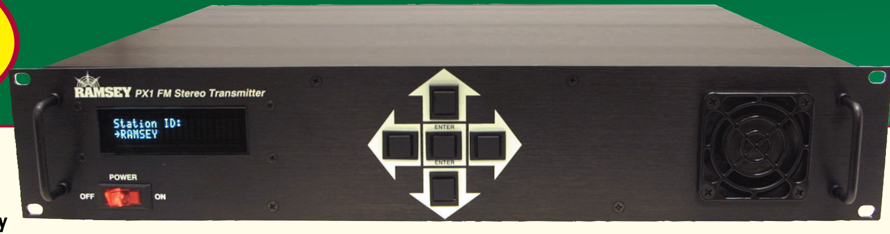
Internet.com's network of more than 160 websites is organized into 16 channels. To find an answer go to:
http://search.internet.com

LUEM42's new cool sites and favorites. About 160 websites are updated monthly.
www.geocities.com/luem42

PC Magazine names the top 100 websites for the period Oct.-Dec. 2003. **www.pcmag.com/category 2/0,4148**,7488,00.asp
PC Magazine, Oct. 2003

FM SUPER SALE

Save Up To $500!



Professional 35W FM Stereo Transmitter

- ✔ 35W output, temperature and VSWR protected
- ✔ Automatic audio & power controls
- ✔ Digitally synthesized PLL for rock solid frequency stability
- ✔ Digital display of all parameters
- ✔ Automatic battery back-up switch
- ✔ 110/220 VAC, 12 VDC operation

35 Watts, Frequency Agile...And Simple To Operate!

USE IT ANYWHERE IN THE WORLD
We designed the PX1 to be the gold standard in transmitters intended for worldwide service. Whether your power main is 110, 220 VAC, or 12 VDC, the PX1 can handle it. Our battery back-up option is ideal for remote areas with questionable power; a standard automobile battery is seamlessly switched in when regular power is lost - your listeners will never miss a beat! Automatic VSWR protection ensures maximum power into any antenna situation that may develop such as ice or wind damaged elements; conditions that would shut competitive transmitters down.

CONTINUOUSLY CHECKS YOUR SYSTEM
PX1 circuitry makes subtle adjustments to various circuit parameters depending upon frequency, temperature, power, audio level, and deviation - in short, it's like having a station engineer constantly monitoring and adjusting on-the-fly! An 8 times oversampled stereo generator with true analog filters throughout assures a clean, refreshing sound image while the RF transmitter chain employs generously rated components for headache-free, long life. The PX1 can also be used as a stand-alone exciter for higher power installations.

EASY INSTALLATION, QUICK SETUP, SIMPLE CONNECTIONS!
Installation of the PX1 is a breeze. A standard Type-N connection is provided for RF Output. Balanced (XLR) left and right audio inputs are provided to properly interface with any source you have. In addition, BNC SCA/Digital inputs are provided along with a quick disconnect connector for a 12 VDC standby/back-up power input. In short, connect your audio sources and antenna, power it up, set frequency and power, and you're on the air! It doesn't get any simpler! All of this in a compact 3.5" standard 2 rack unit case.

EXTREMELY VERSATILE, FOR ANY APPLICATION!
Although specifically designed for Domestic LPFM and International stand-alone stations, the PX1's compact size and 12VDC operation make it ideal for a backup transmitter at a commercial station, or as a low power translator station.

FULL FRONT PANEL MONITORING
Operation of the PX1 is simple and intuitive via the front panel switch matrix. All functions, controls, and status are displayed on the 2 line by 20 character vacuum fluorescent display. *(Note: The end user is responsible for complying with all FCC Rules & Regulations within the US, or any regulations of their respective governing body).*

PX1 **Professional 35 Watt Synthesized FM Stereo Transmitter** **WOW!! SAVE $300!** **$1495.95** ~~$1795.00~~

35 Watt Complete FM Stereo "Station In-A-Box"

- ✔ 35 watt FM stereo transmitter
- ✔ Integrated CD player
- ✔ Integrated cassette player
- ✔ Integrated audio mixer
- ✔ Professional microphone and cables
- ✔ Omnidirectional antenna and coax
- ✔ Installed and prewired in a high impact road case!

Get On The Air Quick With The All-In-One Solution!

YOU ASKED FOR IT!
One of the most requested FM broadcast products over the past year has been a "radio station in a box". At first we laughed. What did they mean... in a box? Then as the requests came pouring in, we found out! Overseas customers, as well as some of the new LPFM licensees have a need to quickly "get on the air" at temporary locations or in the interim to their installed studio/transmitter setup. A number of overseas customers also had to originate short term programming from various remote origination sites for disaster preparedness broadcasts! Well, here you go... a radio station in a box!

EVERYTHING IS INCLUDED!
First we took our state of the art PX1 FM Stereo Transmitter and installed it in an impact resistant, rack mount travel case. Then we added the Superscope PAC750 integrated mixer/cassette deck/CD deck. We prewired them, then added a professional microphone and some cables. Finally, we included our 3.4 dB gain omnidirectional FM Broadcast antenna with 100 feet of matching low loss coaxial cable. There you go, a complete radio station, ready to plug in, and be on the air! Just imagine: Show up, open up the case, plug in the AC power, temporarily mount the antenna, connect the coax, and you're all set! The applications are endless! From live remotes to station backup transmitters, our "Station In A Box" is your solution! *(Note: The end user is responsible for complying with all FCC Rules & Regulations within the US, or any regulations of their respective governing body).*

PX1 FM STEREO TRANSMITTER
Complete 35 Watt Synthesized FM Stereo transmitter. Full featured digital display of all operating parameters and easy to operate.

PAC750 INTEGRATED AUDIO SYSTEM
A complete, integrated, professional audio system. Includes an input audio mixer, cassette deck, CD player, with full audio and cueing controls.

FMA200 OMNIDIRECTIONAL VERTICAL ANTENNA
This 5/8 Wave omnidirectional antenna gives you 3.4 dB gain over a unity gain antenna. That's more than twice the effective radiated power. That will give you the maximum punch from your temporary location. Quick, on-the-spot assembly specifically for your operating frequency. Easy to mount on any mast, tower, or building.

Some customers have even mounted them on the roof of their van, and have operated the station from inside the van! If you're setting up a temporary station this is ideal!

We also include 100 feet of low loss LMR-400 coaxial cable, with connectors pre-installed to get you on the air quick. Just plug it in at both ends!

PROFESSIONAL MICROPHONE, STAND, AND CABLES
Professional handheld dynamic microphone, 25' professional XLR microphone cable, and a matching desk stand.

PXB35 **Professional 35W FM Stereo Station In A Box** **WOW!! Get On The Air QUICK** **SAVE $500!** **$3295.95** ~~$3795.00~~

Circle #30 on the Reader Service Card.

AM & FM Broadcast Kits
Have Fun And Save $$!

Professional FM Stereo Radio Station

- ✔ Synthesized 88-108 MHz with no drift
- ✔ Built-in mixer - 2 line inputs, 1 mic input
- ✔ Line level monitor output
- ✔ High power version available for export use

The all new design of our very popular FM100! Designed new from the ground up, including SMT technology for the best performance ever! Frequency synthesized PLL assures drift-free operation with simple front panel frequency selection. Built-in audio mixer features LED bargraph meters to make setting audio a breeze. The kit includes metal case, whip antenna and built-in 110 volt AC power supply.

FM100B	**Super-Pro FM Stereo Radio Station Kit**	$259.95	~~$269.95~~
FM100BEX	**1 Watt, Export Version, Kit**	$329.95	~~$349.95~~
FM100BWT	**1 Watt, Export Version, Wired & Tested**	$399.95	~~$429.95~~

WOW!! SAVE!!

Professional 40 Watt Power Amplifier

- ✔ Frequency range 87.5 to 108 MHz
- ✔ Variable 1 to 40 watt power output
- ✔ Selectable 1W or 5W drive

At last, the number one requested new product is here! The PA100 is a professional quality FM power amplifier with 30-40 watts output that has variable drive capabilities. With a mere one watt drive you can boost your output up to 40 watts! And this is continuously variable throughout the full range! If you are currently using an FM transmitter that provides more than one watt RF output, no problem! The drive input is selectable for one or five watts to achieve the full rated output! Features a multifunction LED display to show you output power, input drive, VSWR, temperature, and fault conditions. The built-in microprocessor provides AUTOMATIC protection for VSWR, over-drive, and over-temperature. The built-in fan provides a cool 24/7 continuous duty cycle to keep your station on the air!

PA100	**40 Watt FM Power Amplifier, Assembled & Tested**	$549.95	~~$599.95~~

WOW!! SAVE!!

Synthesized Stereo FM Transmitter

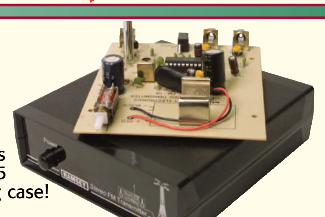
- ✔ Fully synthesized 88-108 MHz for no drift
- ✔ Line level inputs and output
- ✔ All new design, using SMT technology

Need professional quality features but can't justify the cost of a commercial FM exciter? The FM25B is the answer! A cut above the rest, the FM25B features a PIC microprocessor for easy frequency programming without the need for look-up tables or complicated formulas! The transmit frequency is easily set using DIP switches; no need for tuning coils or "tweaking" to work with today's 'digital' receivers. Frequency drift is a thing of the past with PLL control making your signal rock solid all the time - just like commercial stations. Kit comes complete with case set, whip antenna, 120 VAC power adapter, 1/8" Stereo to RCA patch cable, and easy assembly instructions - you'll be on the air in just an evening!

FM25B	**Professional Synthesized FM Stereo Transmitter Kit**	$119.95	~~$139.95~~

WOW!! SAVE!!

Tunable FM Stereo Transmitter



- ✔ Tunable throughout the FM band, 88-108 MHz
- ✔ Settable pre-emphasis 50 or 75 µSec for worldwide operation
- ✔ Line level inputs with RCA connectors

The FM10A has plenty of power and our manual goes into great detail outlining all the aspects of antennas, transmitting range and the FCC rules and regulations. Runs on internal 9V battery, external power from 5 to 15 VDC, or an optional 120 VAC adapter is also available. Includes matching case!

FM10C	**Tunable FM Stereo Transmitter Kit**	$39.95	~~$44.95~~
FMAC	**110VAC Power Supply for FM10A**		$9.95

WOW!! SAVE!!

Professional Synthesized AM Transmitter

- ✔ Fully frequency synthesized, no frequency drift!
- ✔ Ideal for schools
- ✔ Microprocessor controlled

Run your own radio station! The AM25 operates anywhere within the standard AM broadcast band, and is easily set to any clear channel in your area. It is widely used by schools - standard output is 100 mW, with range up to ¼ mile, but is jumper settable for higher output where regulations allow. Broadcast frequency is easily set with dip-switches and is stable without drifting. The transmitter accepts line level input from CD players, tape decks, etc. Includes matching case & knob set and AC power supply!

AM25	**Professional Synthesized AM Transmitter Kit**	$89.95	~~$99.95~~

WOW!! SAVE!!

Tunable AM Transmitter

- ✔ Tunes the entire 550-1600 KHz AM band
- ✔ 100 mW output, operates on 9-12 VDC
- ✔ Line level input with RCA connector

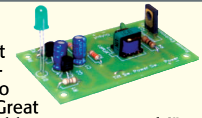
A great first kit, and a really neat AM transmitter! Tunable throughout the entire AM broadcast band. 100 mW output for great range! One of the most popular kits for schools and scouts! Includes matching case for a finished look!

AM1C	**Tunable AM Radio Transmitter Kit**	$29.95	~~$34.95~~
AC125	**110VAC Power Supply for AM1**		$9.95

WOW!! SAVE!!

Mini-Kits...
Great Starters!

Tickle-Stick



The kit has a pulsing 80 volt tickle output and a mischievous blinking LED. And who can resist a blinking light! Great fun for your desk, "Hey, I told you not to touch!" Runs on 3-6 VDC

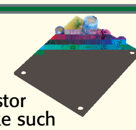
TS4 **Tickle Stick Kit** **$12.95**

Super Snoop Amplifier

Super sensitive amplifier that will pick up a pin drop at 15 feet! Full 2 watts output. Makes a great "big ear" microphone. Runs on 6-15 VDC

BN9 **Super Snoop Amp Kit** **$9.95**

Dripping Faucet



Produces a very pleasant, but obnoxious, repetitive "plink, plink" sound! Learn how a simple transistor oscillator and a 555 timer can make such a sound! Runs on 4-9 VDC.

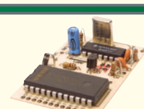
EDF1 **Dripping Faucet Kit** **$9.95**

LED Blinky

Our #1 Mini-Kit for 31 years! Alternately flashes two jumbo red LED's. Great for signs, name badges, model railroading, and more. Runs on 3-15 VDC.

BL1 **LED Blinky Kit** **$7.95**

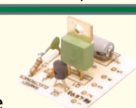
Touch Tone Decoder



Strappable to detect any single DTMF digit. Provides a closure to ground up to 20mA. Connect to any speaker, detector or even a phone line. Runs on 5 VDC.

TT7 **DTMF Decoder Kit** **$24.95**

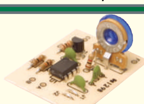
Electronic Siren



Produces the upward and downward wail of a police siren. Produces 5W output, and will drive any speaker! Runs on 6-12 VDC.

SM3 **Electronic Siren Kit** **$7.95**

Universal Timer



Build anything from a time delay to an audio oscillator using the versatile 555 timer chip! Comes with lots of application ideas. Runs on 5-15 VDC.

UT5 **Universal Timer Kit** **$9.95**

Voice Switch

Voice activated (VOX) provides a switched output when it hears a sound. Great for a hands free PTT switch, or to turn on a recorder or light! Runs on 6-12 VDC and drives a 100 mA load.

VS1 **Voice Switch Kit** **$9.95**

Tone Encoder/Decoder

Encodes OR decodes any tone 40 Hz to 5KHz! Add a small cap and it will go as low as 10 Hz! Tunable with a precision 20 turn pot. Runs on 5-12 VDC and will drive any load up to 100 mA.

TD1 **Encoder/Decoder Kit** **$9.95**

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Understanding, Designing, and Constructing Robots and Robotic Systems

Personal Robotics

All About the Isopod™

Isopod: *Any of numerous crustaceans of the order Isopoda, characterized by a flattened body bearing seven pairs of legs and including the sow bug* (**www.dictionary.com**).

Well, that's the dictionary definition, but what it means to me, is a small, flat microcontroller system on a board, with many groups of functions, a board suitable for controlling many actuators, and reading many sensors.

In the last two years, the IsoPod has grown in popularity, and even graced the top 100 products of the year in *EDN* magazine in 2002. It has grown into a family of related products with more functions or smaller dimensions to accommodate the task at hand whatever it is.

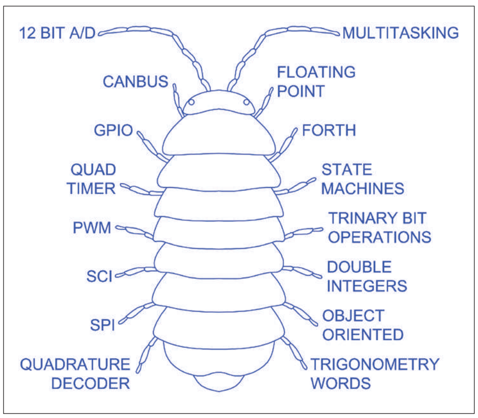
When you buy an IsoPod, you are not just buying a microcontroller board; you are actually buying a digital signal processor, voltage regulators, communications transceivers, and a full-featured programming language called IsoMax™. All this comes on a 1.27" by 3.05" board that looks more like a studded breakfast bar than a microcontroller. Based on the 56800 series of digital signal processors and running at 80 MHz, you will find that fully tasking it will be quite a challenge.

The feature set of the IsoPod is impressive, to say the least. To fully understand its power, you have to consider that all of its features are hardware based. What this means, is that you have access to a lot of "set it and forget it" functionality. The advantage to this is that there is little or no processor overhead required to get a lot of stuff done. This frees you to write the software that imbues your project with the behavior you are interested in, without having to code the functionality.

As an example, you can program just about any microcontroller to drive a multitude of R/C servos, but how much overhead does this require? With the IsoPod, 26 R/C servos can be driven without intervention on the part of the software, Yes, that is correct, 0% overhead on the processor.

Unfortunately, there is a price for all this functionality. The IsoPod is literally bristling with connections. When you connect to it, you really have to be careful to avoid connecting the wrong signals or permanent damage can result, especially to the analog inputs which will in no way tolerate over-voltage. In addition, there is a weird sort of right angle connector on one end, but this has been phased out in the other members of the IsoPod family.

The PWM module is very complete. With two banks of six PWM pins, PWMA, and PWMB, you can instantly control 12 R/C servos, and a variety of different configurations of H-bridges for driving a variety of different motors. Each bank has its own frequency setting, so you could have six R/C servos connected to PWMA, and six DC motors off of PWMB.



The PWM pins in each bank can be configured as pairs, complete with dead-time insertion and polarity control, or as individual pins. You are limited to all pairs or all individuals in each bank, but because of the reasons for using one or the other, this would rarely be an issue. One limitation is the minimum frequency they can generate. Without slowing down the processor to half speed, you are limited to 76 Hz. This can cause problems with some R/C servos, but so far, my experience has been okay. In any case, if it is a problem, there are the timer registers that can also generate PWM, and can easily go as slow as necessary to drive R/C servos.

The timer module is hands down the most versatile part of the IsoPod. Consisting of four banks of timers (TA-TD), it can generate PWM, read quadrature encoders, decode step/direction signals, count pulses, or measure pulse lengths. For instance, I have an application that has the timer unit configured to read six quadrature encoders into 32 bit counters, and perform high-resolution pulse measuring on each encoder, to provide ultra-high resolution velocity information. I have yet to scrape the surface of its functionality. Covering an address space of 128 bytes, it is quite a bit to get acquainted with.

The GPIO module is fairly straightforward, with two full banks

of eight pins each available on one header, and a smattering of port pins on dedicated connectors. It is fairly generic in its implementation. One really nice feature is having three LEDs onboard for debugging purposes.

The analog is a bit more complicated than the GPIO, but not by much. It is comprised of two banks of four 12-bit A/D converters. They are a bit persnickety in that it is recommended they only be used in the 0-3.0 volt range, which makes interfacing voltage output sensors a bit of a hassle. But that's nothing a voltage divider and a bit of Ohm's Law can't handle.

The communications sections are also really quite powerful. To start, there are two asynchronous serial ports of which the second one can be ordered as standard RS-232, RS-422, or RS-485. The one drawback here is that the highest standard baud rate is only 38400. Nonetheless, having two hardware based serial channels is really useful.

There is also a single SPI port which can run at up to 20 MHz, and can be configured as either a master or a slave. On its connector, there are the necessary SPI signals, and a couple of port lines, the reset line, Gnd, +5, and +3.3 V. This makes interfacing to other devices really easy.

In addition, there is a basic implementation of CANbus on board. While not a "full implementation", it is still good enough for most CANbus tasks where it isn't responsible for being the master of the bus where a high level protocol is being used. This really isn't an issue, since most of us won't be spending the licensing fees to implement the popular CAN protocols. We will simply be writing our own, or at worst, building slaves that do follow a higher protocol. In any case, with error checking, checksumming, automatic re-transmission, and bus conflict arbitration, CANbus holds a lot of promise. New Micros was even good enough to put a CAN transceiver chip on board.

Now, before I delve into the native language of the IsoPod, I want you to sit back and ponder what you can do with the IsoPod. Even if you are a dyed-in-the-wool Intel, Atmel, PIC, or

even BASIC Stamp user, the different communications methods, combined with its full set of hardware features offered on the IsoPod make it the ideal universal peripheral. You could easily use it as an R/C servo engine, quadrature reader, sensor reader, and spoon-feed the data to and from your microcontroller or microcomputer of choice. There are many users who have gone this route, then find themselves handing more and more processing power to the IsoPod.

The IsoMax programming language supplied with the IsoPod is really quite unique as well. IsoMax is actually a superset of FORTH, an arcane and venerable language often associated with users who have almost a religious reverence for it. While covering FORTH is beyond the scope of this article, IsoMax incorporates enough sufficiently novel concepts that it is worth mentioning.

The lack of FORTH's popularity, in my opinion, is that it is really a language construction set. When you define a function, you actually end up factoring it into common elements, and re-using them over and over again. In doing this, you are writing what I call MYFORTH, and everybody's MYFORTH is different. Back when everyone was trying to classify and sort the different languages out there, FORTH was left looking a bit chaotic. This has lead to finding documentation difficult. You will not drive to your local mall, grab a coffee, and decide which FORTH text you are going to buy. Fortunately, there is enough documentation on New Micros' website to get you going.

To begin, the most novel thing about IsoMax is the fact that it actually lives in the IsoPod itself. All you need is a serial port, terminal software, and a power supply. I often start a project by simulating the hardware on my desktop, and getting the bulk of my program code going before it even sees the real hardware it will be working with.

The other truly unique thing about IsoMax is that it is multitasking, and even the multitasker is implemented in a unique way. The multitasker is actually time-synchronous. What this means is that you establish a frequency at which all of your processes — called virtual machines — get run, and the multitasker runs them one by one, in the order you want them to be run. In essence, you break the flow of time into granules. In every granule of time, everything gets done.

Another neat thing about the multitasker is that while your programs are running, you can actually still communicate with the processor during the foreground task slice. You can set or read registers, change the contents of variables, even write new words that get compiled.

This does take a bit of getting used to, but it does work well once you get the hang of it. One potential drawback of this method is synchronization to other hardware that operates at a different (or even variable) period than the IsoPod. This has been overcome by adding data buffers to the serial lines, for instance. The buffer stores the data transparently in the background, and presents it to you when you ask for it. The one exception here is that the CANbus does not have a buffer like this in the classical sense, but it does receive eight bytes of data at a time. Since the implementation of the buffers, I have not been troubled by the synchronous nature of IsoMax.

This brings me to another point. IsoMax, currently at V0.6, is a language in flux. While I believe it is finished, it is not fully accessorized to the level that New Micros wants it to be. This means that improvements will happen and, in fact, have happened through the versions, but the net effect is always a better platform to work from.

Because the sheer volume of registers for hardware access is mind numbing at times, IsoMax incorporates very high-level object-oriented words. I like to call them template words. They are great for the beginner, and can help you get something up and running quickly, but some of them are notoriously slow. The reason for their slowness is that every time you use them, they have to "pave the way" for themselves. They make no assumptions; they configure each and every register that is required, each and every time they are called. I usually start out with them, and then if things show signs of slowing up, I go through and replace them with lower level code. They are also handy for seeing how registers get configured when you use them. This makes them ideal as a teaching tool.

Interestingly enough, IsoMax also provides words called trinaries for working with numbers at the bit level that are lightning fast. Trinaries allow you to read, test, and set registers or other memory locations at the bit level. They are great for reading buttons or registers, or changing a register's contents rapidly.

Another unique thing about IsoMax is the way it handles flow control. While its FORTH underpinnings are available for stodgy FORTH users, IsoMax prohibits the use of loops in procedural sections entirely. IsoMax allows you to have running indexes to track how many times things have been run, which is really the essence of using a loop. In IsoMax™, if you put an endless loop inside the procedural portion of a Virtual Machine, I guarantee you the system will crash.

Another interesting addition to IsoMax is finite state machine flow control, or FSM. This is a novel approach to programming embedded systems, and has real applications in the fields of control and robotics. State machines perform a function similar to if-then-else statements, but the end result is a direct line to the output you are interested in, not a rat's nest of multiple nested conditionals. This results in easier programming and faster program execution, because you only test inputs related to a particular state, instead of all possible inputs and computations every time.

In IsoMax, a Mealy model of state machine is used, as they tend to be more efficient in the number of states required. But Moore model machines can also be simulated in the language. State machines are close in concept to inference engines used in expert systems and Artificial Intelligence, and some are implemented that way. Today, state machines are seeing wide usage in the video game industry, and are particularly useful for communications protocols, and compiler design.

Overall, the IsoPod is an extremely flexible system on a board. To illustrate this point, I have shelved my PICs, 68332s, and 68HC11s in favor of the IsoPod. It's the micro I like to reach for first! **NV**

The Latest in Networking and Wireless Technologies

Open Communication

ETHERNET — PART 2: Wireless LANs

In the last Open Communications column, I covered wired Ethernet. This is the universe's most popular local area network (LAN) whose physical layer (PHY) or transmission medium is usually category 5 or 6 (CAT5/6) twisted pair or fiber optic cable. Now, a wireless version of Ethernet is quickly expanding Ethernet LANs and creating a whole new way to access the Internet from almost anywhere.

Known by its IEEE (Institute of Electrical and Electronic Engineers) standard number 802.11, wireless Ethernet is extending the LAN outside of the enterprise and small businesses into homes, airports, restaurants, hotels, and many other public areas. Like the cell phone, wireless Ethernet lets you stay in touch with your Email while you are on-the-go via your laptop or PDA. Wireless Ethernet is certainly revolutionary rather than evolutionary in the development of Ethernet.

Background

Radio-based LANs first showed up in the mid-1980s but they were large, expensive, and had low data rates. While a few companies adopted them, it has not been until the late 1990s that wireless local area networks (WLANs) really took off in the marketplace. What made the difference was all of the work put in by companies to form a universal standard that could be used world wide.

After years of work, the IEEE WLAN standard 802.11 was ratified in 1997. This gave us 1 and 2 Mbps (millions of bits per second) connectivity. Then in 1999, a revised standard 802.11b was formalized. That standard — which offers an 11 Mbps data rate — made wireless Ethernet instantly acceptable. Today, WLANs are the fastest growing segment of the electronics industry. Furthermore, even newer, faster versions have been developed, approved, and converted into rapidly selling products.

Another reason for the growth and success of 802.11 WLANs was the establishment of the Wi-Fi Alliance. Wi-Fi, meaning wireless fidelity, is the trade name for the organization of equipment, chip, and software companies making WLAN products. While the existence of a standard helps ensure that equipment made by one company works with that of another, it is no guarantee. As it turned out early on, there were enough interoperability glitches and issues to make companies get together and solve these problems.

The Alliance was set up to provide testing and certification of WLAN products to ensure interoperability. Companies submit their products to Wi-Fi for testing and, if they meet the rigid specifications, they are blessed with the Wi-Fi label. The Wi-Fi effort removed the last doubt about the interoperability of WLAN products from one vendor to another. The market blossomed as a result.

The acceptance of 802.11 products has increased sales exponentially over the past several years thereby decreasing prices and encouraging even greater adoption. This is truly one of the most successful wireless products ever, other than the cell phone. If you don't know about or use this technology, it's time to get on board, as surely it will affect you or provide you with a communications option that can benefit your life.

FIGURE 1. Typical WLAN plug-in adapter for laptops. Courtesy SMC Networks.

Benefits

What makes WLANs so popular? It's simple. People love their freedom and mobility. Just as most of us have become addicted to our cell phones, so have many become addicted to Email and Internet access. It is a great benefit to be able to access your Email and the Internet from anywhere with your laptop. It lets those in companies move from office to office with their PC and it allows you to take your laptop to meetings in conference rooms and other offices without losing touch.

In addition, you can now use your laptop from an airport, restau-

rant, or other local place with a wireless connection. At home, it is pure pleasure to do any computer work from your deck, patio, or easy chair without dragging a long, twisted pair cable. Flexibility, mobility, and freedom made WLANs the reigning LAN configuration.

So, as companies expand their Ethernet LANs, they are going wireless. There is no messy and expensive wiring to add and no reconfiguration hassles if people move offices, and it adds the mobility that people love. But the real revolution has been the development and deployment of public access points called hot spots. They first showed up in airports and now most major airports have one or more such access points. Hotels began adding hot spots about the same time and now most major chains offer this as a guest benefit.

Coffee shops, like Starbucks, also have wireless access. Some McDonald's also offer this service. And it is becoming more popular than ever in convention centers. Today, we have over 12,000 hot spots to choose from, but some projections say that we can expect over 100,000 by 2007. Thanks to technology, you can take it with you.

How it Works

Wireless Ethernet is implemented with sophisticated microwave radio transceivers. Every PC or server contains a digital two-way radio that sends and receives Ethernet formatted data. Also known as radio modems or wireless adapters, these interfaces appear in several forms. They can be plug-in cards for regular desktop PCs or PCMCIA cards for laptops. See Figure 1.

External transceivers that connect via a USB port are also available. Many of the newer laptops come with Wi-Fi radios built in. Intel's widely promoted Centrino chip set is an example of an embedded Wi-Fi interface. Each of these transceivers forms one node in the LAN. Finally, there is the transceiver that is part of what is called the access point (AP). Also known as a wireless gateway or router, this is the unit that services all the remote transceiver nodes. Figure 2 shows a typical home networking access point.

In a large enterprise or small company LAN, the AP is connected to the existing wired Ethernet LAN by the usual twisted pair line. The AP is mounted high on a wall or ceiling so that its antenna has a good "view" of the area it is to cover. Then, many radio modem equipped PCs or laptops in that area can communicate with the LAN via the gateway. The radius of the coverage is from 100 to 300 feet, depending upon the environment, especially if walls, ceilings, and floors are involved.

The connection at a hot spot has the gateway or router connected back to an Internet service provider (ISP), usually by way of a leased T1 or T3 line. At home, the gateway or router is usually connected to a high speed broadband Internet source, such as a cable TV or DSL modem. The gateway usually provides coverage for the whole house.

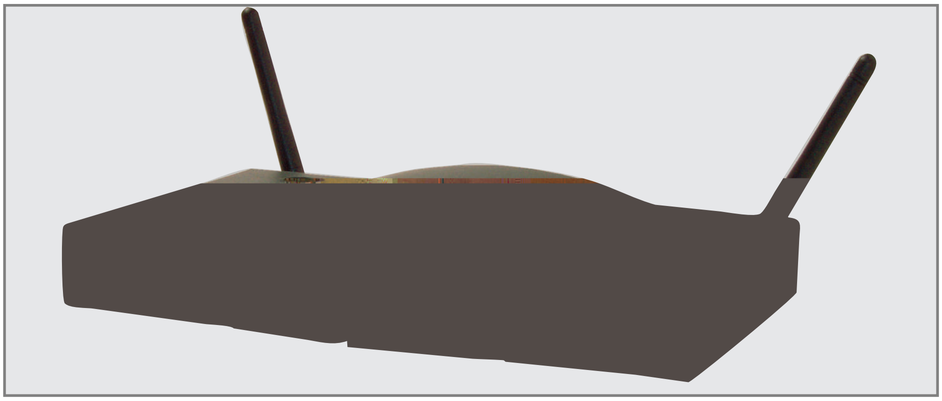
The Standard

The 802.11 standard is not just one standard, but many. By far, the most popular is the 802.11b standard that almost everyone uses today. 802.11b defines what we call the PHY and MAC layers of a multilayer protocol scheme that Ethernet uses. PHY means physical layer, which, in this case, is radio. The standard defines what we call the air interface. The MAC, or media access control layer, takes care of all the addressing, formatting, and transmission between the air interface and the network.

The PHY in 802.11b uses the unlicensed 2.4 GHz industrial-scientific-medical (ISM) band defined in the FCC's Part 15 rules and regulations. This band is 83.5 MHz wide and is divided into 11 overlapping 22 MHz wide channels. Since only three of the channels are non-overlapping, these are the only useful ones that do not interfere with one another. Their center frequencies are 2.412, 2.437, and 2.462 GHz. With 22 MHz of bandwidth, it is possible to achieve a data rate up to 11 Mbps. But, of course, that data rate also depends upon the range of transmission, the environment, as well as sources of interference and noise.

The 802.11b standard specifies the use of direct sequence spread spectrum (DSSS). This is a technique that takes the raw serial binary data and exclusive ORs it with a unique high speed chipping code. The result is a high speed serial signal that is then modulated onto the carrier. The 802.11b standard specifies multiple modulation methods depending upon the speed of transmission. If the environment is favorable and the transceivers are within range and noise and interference are at a minimum, the maximum data rate can be achieved.

FIGURE 2. A common home network access point or wireless broadband router. Check out the dual antennas for diversity reception. Courtesy SMC Networks.



802.11b uses complementary code keying (CCK) to get 11 Mbps. This method transmits eight bits per modulation symbol (carrier phase).

If the range and environment conditions are not ideal, the speed of the radio automatically backs off a predetermined lower speed to ensure reliable data transmission. This lower speed is 5.5 Mbps, also using CCK. If conditions worsen, the speed drops further to 2 Mbps, using DQPSK (differential quadrature phase shift keying) or a low of 1 Mbps, using plain old ultra reliable DBPSK (differential binary phase shift keying).

As for range, it really varies depending upon local conditions. Normally, microwave transmissions are strictly line-of-sight (LOS), meaning that the receive antenna must "see" the transmitting antenna. However, if sufficient power is available, the signal will punch through walls, floors, ceilings, office dividers, and even trees and other buildings. Obviously, the signal is greatly weakened as it passes through these obstacles.

Range is also a function of transmitter power and the antenna. With most equipment, you can rely upon a range of about 100 feet radius from the gateway antenna. This assumes an omnidirectional antenna and the standard 100 mW of transmitter power. A directional gain antenna will boost the range significantly. By using more power and a gain antenna high up and in the clear, you can achieve a range up to several miles. In some rural communities, 802.11b Wi-Fi networks, with higher power and high-mounted outdoor antennas, have been set up to give high speed broadband Internet access to those without cable or DSL lines.

A newer standard 802.11a was ratified in 2001. It uses the FCC designated U-NII or Unlicensed National Information Infrastructure band in the 5 GHz range. This band is far less crowded than the already over subscribed 2.4 GHz band. Besides microwave ovens, cordless phones, Bluetooth wireless devices, HomeRF wireless networks, and now jillions of Wi-Fi transceivers, it is a miracle that any reliable communications can be obtained in the 2.4 GHz band.

If interference is a problem as it is for some, the 802.11a equipment gives you all the benefits of a WLAN and with even higher speed and virtually no interference. Using orthogonal frequency division multiplexing (OFDM) — a form of wide band modulation — speeds up to 54 Mbps are possible. The range is a bit less at 5 GHz but is satisfactory for most applications. The speed backs off to 48, 36, 22, or 11 Mbps, as conditions deteriorate.

The most recent version of the standard is 802.11g, which was ratified last year. This version specifies operation in the 2.4 GHz band, but, by using OFDM, it can achieve an upper speed of 54 Mbps. And it is fully backwards compatible with 802.11b. This option, which is now becoming available in most products, gives you 802.11a speed over 802.11b range. While most networks and hot spots still support only the 802.11b standard, many will soon upgrade to the g version. And the a version will also grow, especially in companies where interference is a problem.

Chip companies are recognizing

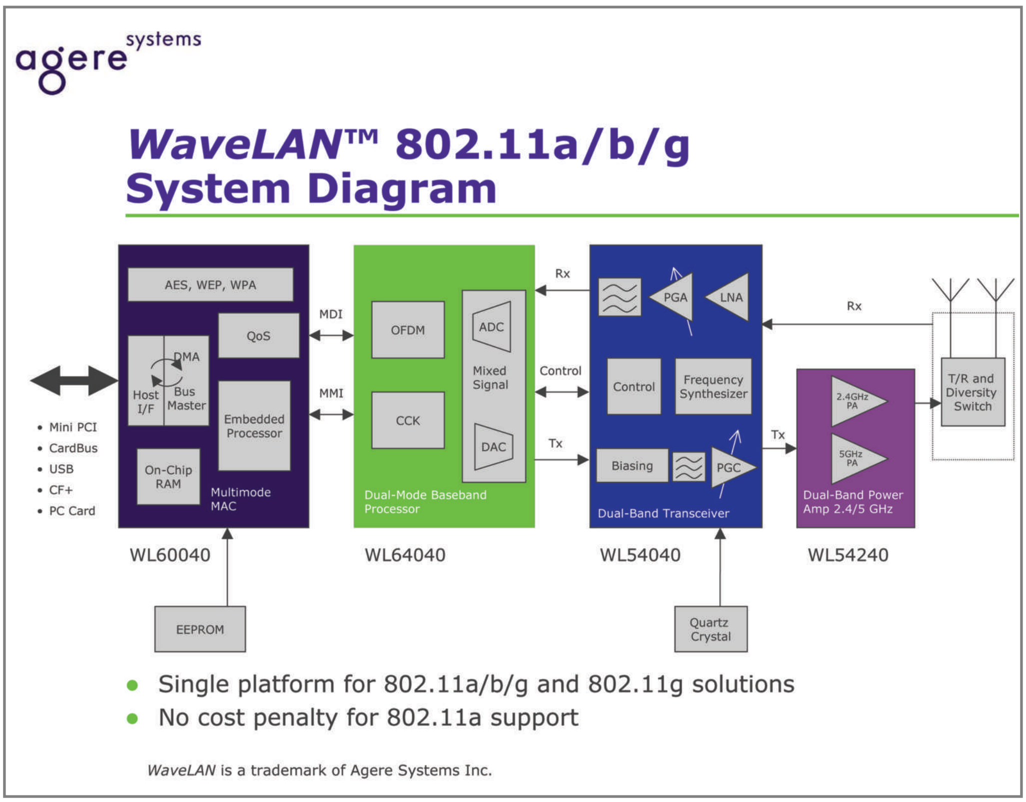


FIGURE 3. Agere Systems WaveLAN chipset for multimode 802.11a/b/g access points and interface cards. The WL54040 is the dual band (2.4 and 5 GHz) transceiver with direct conversion (zero IF) for CCK operation and a low IF for OFDM. The WL54240 is a dual band power amplifier with 24 dBm for 802.11g and 20 dBm for 802.11a. The WL64040 is the multimode processor that handles the A to D and D to A conversions between the transceiver chip and the baseband processor. This chip also does the CCK and OFDM modulation and demodulation. The WL60040 is the MAC baseband with its own embedded processor and provides the encryption, as well as the interfaces to the PCMCIA or CardBus, USB port or other PC connection. Courtesy Agere Systems.

the need for transceivers that comply with all three standards (a/b/g). If you truly want mobility and the ability to connect to anything available, you need an adapter that handles all of them and switches automatically. An example of a chipset that does all three is Agere', as shown in Figure 3.

But that's not all. The IEEE just recently approved a study group to develop the next version of the standard. Tentatively designated 802.11n, this new standard which won't be available for a few years promises data rates from 108 to 320 Mbps.

Critical Issue

If WLANs are so great, why isn't everyone using them? The answer to that question is usually one word: security. Almost anyone can pick up a wireless signal. With a sensitive receiver and a directional antenna, you can easily eavesdrop on almost any WLAN. If you are transmitting sensitive information, this is not something you want to take a chance on. There have been numerous examples of hackers sitting in a parking lot of a major retailer stealing credit card numbers from the 802.11b-based cash registers and credit card scanners.

The creators of the 802.11 standard anticipated the security problem and provided for encryption. Known as Wireless Equivalent Protocol (WEP), this capability is built into every Wi-Fi chipset. It does provide a minimum data encryption process that can protect most information. WEP is not turned on automatically, meaning the user has to enable it. For that reason, most users don't use it. It is rarely used in home networks or at hot spots. Many companies do not enable it despite their need for security.

WEP has also proven to be vulnerable to hacking. Some Wi-Fi vendors, like Cisco, have come up with their own security/encryption measures like the Temporal Key Integrity Protocol (TKIP). The Wi-Fi Alliance developed an improved interim solution called the Wi-Fi Protected Access (WPA). Both of these are included in most transceivers.

The IEEE has also developed new security techniques under its 802.11i standard for encryption and 802.11x for authentication. If that is not enough, many companies have implemented virtual private networks (VPNs), a popular technique for securing the transmission of data over the Internet, to handle their wireless networks. So, while security is an issue, there are many solutions for those who want and need to send sensitive data over their WLAN.

Antennas: The Key to a Successful WLAN

While the reliability of a wireless connection depends on a variety of factors, many of them are beyond your control. Transmitter power is one. With most units you get the maximum allowable power, usually 100 mW. Next is AP location. You can control this to some extent. You should place your AP high and in the clear so it sees as many of the remote nodes as possible. If possible, experiment with the location of the access point for best overall results. In some cases, you may find that you need more than one access point. This is especially true in large companies with lots of employees and space to cover.

A real help for those installing multiple APs is the IEEE's newly approved 802.3af standard, also called Power over Ethernet (PoE). This standard provides a way to send a DC voltage over the standard CAT5 or CAT6 twisted pair Ethernet cable. In this way, the AP does not need a separate AC or DC power source which can be a problem in placing an AP in an optimum location. Most of the newer access points now come with PoE capability.

One thing you do have control over in your AP is your antennas. While all access points and wireless adapters come with an antenna, sometimes you have a choice. Select

an antenna that fits your plan. An omnidirectional unit is best if you have lots of space to cover in all directions. But, if all of your wireless clients are off in one direction, you may want to consider a directional antenna that focuses power where you need it. Such directional antennas exhibit gain and give the same effect as increasing transmitter power. Some typical directional antennas are the ever popular Yagi, as well as vertical collinears and the flat patch antennas.

Most home access points have dual antennas for receive diversity that helps improve performance. The antennas are spaced from one another by at least one wavelength and the receiver switches between them to see which gives the best signal. Refer to Figure 2 again. After market antennas are also widely available so if you need to fix a problem or improve reliability, experiment with the antennas.

WLANs: What's in it for You?

Actually, there is something for everyone. If you are thinking of extending your company's Ethernet LAN, give some serious thought to 802.11. It offers many benefits. It improves work productivity because of the mobility it provides. You can do company work from anywhere. It also simplifies installation. No need to pull cables. This reduces labor and materials cost. Free space is ... duh ... free. Users can move offices or do work wherever. And the network also scales better as the number of users grows.

As an individual, you may want or need the ability to work while traveling. Road warriors — those people who travel frequently for their companies — are real big fans of WLANs because they can stay in touch by laptop and hot spots with Email and have Internet access virtually anywhere. Even some new PDAs are getting Wi-Fi capability thanks to the lower power chipsets. If you don't have Wi-Fi service now, you will find that your productivity will increase tremendously on the road if you do.

For consumers, a WLAN is also a viable option. The cost of setting up a home network with Wi-Fi is less than $200.00 today and getting lower. You can get a wireless access gateway or router for under $100.00 if you shop around. Add a few bucks more for the adapter card and you are on your way. No need to do any wiring. If you have a laptop, be prepared to rapidly get addicted to the freedom that wireless provides.

P.S. I've been writing this column for over a year now. I have lots of great ideas for future installments, but I would like to hear what you want to read about. Do you want more tutorial articles, like how spread spectrum or OFDM work, or would you like to see more hands-on construction/applications articles on wireless? What about ham radio or SWL? Drop me a line via Email (**lfrenzel@sbcglobal.net**) and give me your wish list. **NV**

Cool Websites

Institute of Electrical and Electronic Engineers
grouper.ieee.org/groups/802/dots.html
This is the Ethernet standards website with more than you ever wanted to know about it.

Wi-Fi Alliance
www.wi-fi.com
The trade association that certifies 802.11 WLAN equipment.

Palo Wireless
www.palowireless.com
A general website with tons of data on WLANs and lots of other wireless technologies.

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Putting the Spotlight on BASIC Stamp Projects, Hints, and Tips

Stamp Applications

Makin' It Motorized

From discarded toy — to mobile robot!

I don't know about you, but I'm still exhausted by last month's column — wow, that was a real workout, wasn't it? I do hope you found it useful though. This month, we're going to go a lot easier, but still have a bunch of fun! And after its terrific comeback the last couple of months, we're going to have that fun with the venerable BASIC Stamp 1.

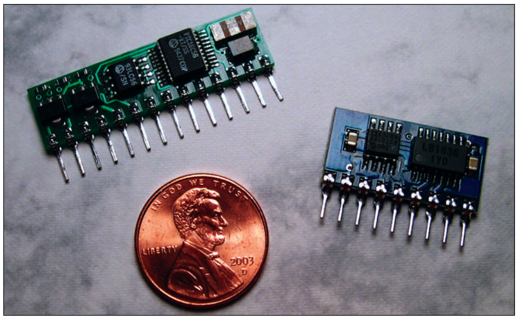


Figure 1. The Pololu Motor Controller (right) with a BS1 module.

There's no denying that personal robotics is one of the fastest growing aspects of hobby electronics. There are clubs all across the globe devoted to it, and each week seems to bring another television show with robotics as its centerpiece. An easy way of getting started in homegrown robotics is to convert an existing motorized toy. They're all over the place, in fact, your family may have a few left over from the holidays that no longer seem interesting. Why not spice up an old toy with a brain you can program yourself? Okay, then, let's do it.

Micro Motor Control

Since virtually all motorized toys use small DC motors, and controlling them requires full-time PWM that we can't do natively with the Stamp, we'll use an external motor controller. Pololu Corporation makes and sells components devoted to small robotics and their Micro Dual Serial Motor Controller is perfect for our task of converting a motorized toy. The SMC02 accepts instructions through a serial connection and will control two motors (speed and direction). Motor voltage can be from 1.8 to 9 volts, with currents up to one amp per motor! This little dude rocks. And little is accurate; you can see what it looks like in Figure 1 next to a penny and a BS1-IC module.

Let's get right into it. A typical first robotic project is a "bumper bot" — the kind of robot that when it bumps into an obstacle will turn away and then keep moving. There are BS2 examples of this kind of robot everywhere; I wanted to see if there was enough space in the BS1 to pull it off. As it turns out, there is with room to spare, which means we can add more "intelligence" to our robot once we get in going.

Figure 2 shows the schematic for our simple robot controller. Two pins are used to communicate with the Pololu controller (SMC02), two others for our bumper inputs (using our standard "safe" circuit). The first control line to the SMC02 is the serial connection. The SMC02 will automatically detect baud rates from 1200 to 19.2 kBaud. As our top-end limit on the BS1 is 2400, that's what we'll use. The second line controls the Reset input to the SMC02. Using the hard reset line will let us stop both motors at once when required without having to send serial commands.

While interfacing to the SMC02 is simple and straightforward, it is very specific. Let's have a look at the set-up portion of the program:

```
Setup:
  HIGH SOut
  GOSUB Reset_SMC

...

Reset_SMC:
  LOW Reset
  PAUSE 1
  HIGH Reset
  RETURN
```

The first line sets the idle state of the serial connection. Since we're using a "true" mode, this is important so that the start bit (high-to-low transition) of the first transmission is properly detected. Next, the controller is reset by taking the Reset input low and holding there for a millisecond before retuning it high. The Pololu docs suggest that one millisecond is overkill, but I found that at least one millisecond was required for proper operation.

Okay, the robot is now ready to run. Since our only

Figure 2. Bumper-Bot schematic.

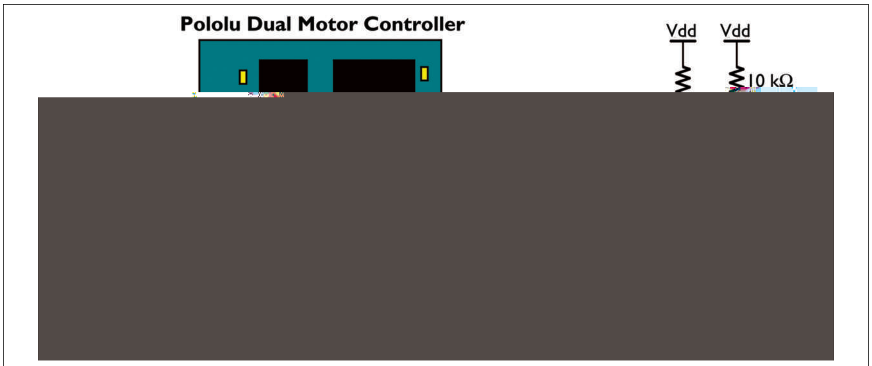
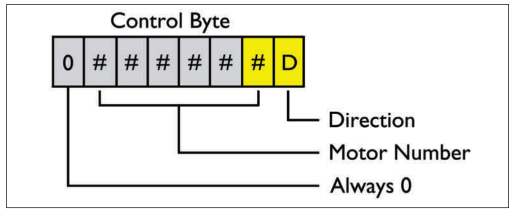


Figure 3. Control byte mapping.



inputs are the bumpers, we'll use them as an indicator to start running the program.

```
Wait_For_Start:
  GOSUB Get_Bumpers
  IF bumpers = %11 THEN Wait_For_Start
  PAUSE 1000

...

Get_Bumpers:
  bumpers = PINS & %00000011
  RETURN
```

We start by scanning the bumpers — a very simple task. You may wonder why I would devote a subroutine call to what is, essentially, a single line of code. The answer is optimism. Huh? Well, I'm pretty sure I'm going to do other things with this core code, so I can simply update this section using different sensors without upsetting the rest of the program. Okay, to collect the state of the bumpers we will read the Stamp input pins and mask those that aren't used (Bit2-Bit7).

Since our inputs are active-low, we'll get a value of %11 in bumpers when there is no contact. If this is detected at the start, we will loop back to Wait_For_Start until one or both inputs change. Once a bumper input is detected, the program delays for one second to let us get our hand out of the way.

And now we get to the heart of the program. Before we do, let's look at the serial communication between the Stamp and the Pololu Motor Controller. Communication takes place in four-byte packets like this:

```
  SEROUT SOut, Baud, ($80, $00, control, speed)
```

The first byte of the packet is a sync byte and will always be $80. The second byte identifies the device type and will be $00 for motor controllers. The third byte — control — identifies the motor number and direction (more in a second), and finally, the fourth byte holds the speed (0- 127).

The control byte holds the motor direction in bit 0 (1 = forward, 0 = reverse) and the motor number affected by the command in bits 1-6 (see Figure 3). It may seem odd that there are six bits (0-63) for the motor number when there are only connections for two. If you need to control more than two motors, you can get additional modules that will respond to different motor number sets. The standard unit has a "-1" at the end of the part number. Additional units are labeled "-2", "-3", and so on.

To simplify our program, we can create a set of constants for each motor (left and right) and for each direction.

```
SYMBOL  MLFwd   = %11
SYMBOL  MLRev   = %10
SYMBOL  MRFwd   = %00
SYMBOL  MRRev   = %01
```

The reason for the apparent contradiction of the direction bit for the right motor is that the motors installed in a robot are flipped 180 degrees of each other. In order to make the robot go in one direction, the motors must spin opposite each other. If both motors were going forward or reverse, the robot would just spin in place (we use this fact for turning).

Okay, then, the rest of the code should be easy to understand and it's fairly modular, so we'll go through it a section at a time.

```
Main:
  GOSUB Get_Bumpers
  IF bumpers = %11 THEN Accelerate
  GOSUB Reset_SMC
  speed = SpdMin
  PAUSE 10
  BRANCH bumpers, (Back_Out, Right, Left)
  GOTO Main
```

The purpose of the main loop is to scan the sensors and **BRANCH** to the code section that handles robot direction control. The first check is for a bumper,s value of %11 which means no sensor contact. When there is no sensor contact, we will continue forward and accelerate if not already at top speed. When a bumper input is detected, the SMC02 will be reset to stop both motors, the robot speed will be reset to its minimum, and **BRANCH** is used to select the object avoidance code.

```
Accelerate:
  speed = speed + SpdRamp MAX SpdMax
  SEROUT SOut, Baud, ($80, 0, MLFwd, speed)
  SEROUT SOut, Baud, ($80, 0, MRFwd, speed)
  PAUSE 50
  GOTO Main
```

When the robot isn't bumping into things, it will be allowed to accelerate. The speed is increased up to the SpdMax constant by the value set in SpdRamp. We can control the acceleration by modifying SpdRamp, the delay time, or both.

Our biggest chunk of work will come when we run head on into an object; this is indicated by activity on both bumpers. What we'll want to do is back up, turn out, and then start again.

```
Back_Out:
  SEROUT SOut, Baud, ($80, 0, MLRev, speed)
  SEROUT SOut, Baud, ($80, 0, MRRev, speed)
  PAUSE 250
  GOSUB Reset_SMC
  SEROUT SOut, Baud, ($80, 0, MLFwd, speed)
  SEROUT SOut, Baud, ($80, 0, MRRev, speed)
  PAUSE 500
  SEROUT SOut, Baud, ($80, 0, MRFwd, speed)
  GOTO Main
```

This simple program uses a fixed turn time which will, of course, require adjustment for each robot's specific mechanics (wheel size). A bit of interest can be added by randomizing this delay beyond a specified minimum; this will make the robot look slightly more organic in its behavior.

Turning left or right based on a single bump input is very easy. The motors already been stopped, we simply have to reverse the motor opposite the active sensor, and then proceed forward again.

```
Right:
  SEROUT SOut, Baud, ($80, 0, MRRev, speed)
  PAUSE 200
  GOTO Main

Left:
  SEROUT SOut, Baud, ($80, 0, MLRev, speed)
  PAUSE 200
  GOTO Main
```

Once again, the size of the wheels on our robot will affect how quickly it spins so we may need to adjust the delay timing. Remember that we can "tune" the robot's behavior by adjusting movement delays and speed values. One note is that — depending on the size and weight of your robot — you may need to adjust the SpdMin constant. Some robots will need just a little more oomph to get started.

And there you have it; a simple "bumper bot" using the BS1 — and only about half the code space at that. What this means is that we have ample room to add different "behaviors" to the robot. Let's take a look at one such behavior.

Go to the Light ...

In nature, there are animals that seek light (like moths to a flame). We can mimic this behavior in a robot, and, when we do, we call the robot a photovore. As our eyes detect light, we can use a photocell to detect light levels for the robot. By using two sensors, we can compare the light levels of each and determine the direction the robot should move to seek the light.

Figure 4 shows the connection of a single photocell to the BS1 that will be read with the **POT** function (we'll need two of these circuits for our robot "eyes"). Note that the configuration of the RC components is different that those used with the BS2's **RCTIME** function. The reason for this is that **POT** actually does more than **RCTIME**. The **POT** function charges the capacitor by taking the specified pin high for 10 milliseconds. It then starts a timer and actively discharges the capacitor by taking the pin low momentarily, then changing it to an input and checking to see if the capacitor voltage has dropped below the pin's switching threshold. Scott Edwards wrote a very detailed description of **POT** versus **RCTIME** back in Column #15 (May 1996 — If you don't have the issue, you can download the column as a PDF from the *Nuts & Volts* website).

In order to experiment with photovore code, I created a test program. I will leave it to you to fold it into your robot. The reason I created an experiment program to share here is that I want to encourage you to do the same thing with your projects. Yes, I am a very big proponent of knowing the outcome of a project (having a specification), but we don't have to get there in one step. I frequently get requests for assistance from youngsters who are just starting out and trying to solve everything at once. I'm like a broken record and will continue to suggest that we work with intermediate or experimental programs before "going for the gold."

Okay, so what do we want to do? Knowing that the more light on the photocell will cause its reading to fall, we will read both sensors and move in the direction of the smallest reading. That's the broad stroke. What we'll find, however, is if our logic remains that simple, the robot will be too sensitive and will appear "twitchy." We solve the twitch by adding a threshold to the readings; that is, the difference between the two readings must exceed a certain threshold before we actually move. This helps accommodate differences in components and smoothes things out.

Finally — and I only learned this after running the program a while — we need to accommodate the sensors being subjected to conditions where the readings will fall to zero. Due to the component values used, this can happen in total darkness or when the sensor is bombarded by bright light (swamped).

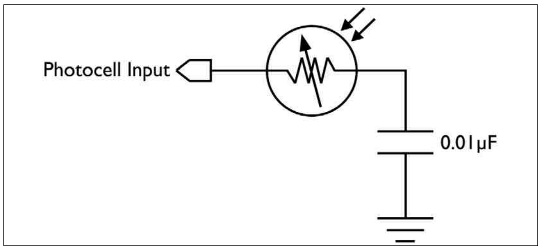


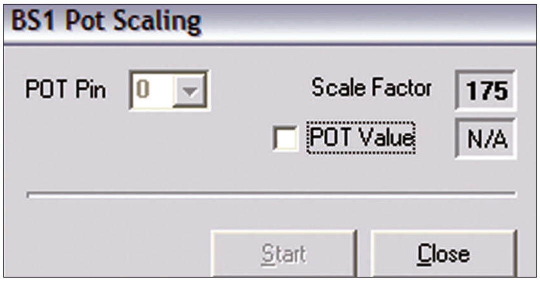
Figure 4. Photocell circuit for the BS1 POT function.

Before we get into the code, we need to run a calibration program to determine the scaling factor required by the **POT** command. Like **RCTIME**, **POT** reads a 16-bit value but it will scale it to 8-bits for the program. The idea is to set the scaling factor such that the maximum value

of the **POT** function is 255.

After connecting our **POT** circuit, we'll select Pot Scaling from the editor's Run menu (Note: This feature became available in Version 2.1, Beta 1). Figure 5 shows the dialog for POT Scaling. We must first select the POT pin from a drop-down. Then when we click Start, a short program will be downloaded to the Stamp (yes, this overwrites the current program). Normally, we would turn the pot until we get the lowest reading in scaling factor. Since we're using a photocell, we adjust its value by shading it from light. I decided to use a translucent foam cup over my components to determine the scale level (max resistance).

Figure 5. **POT** Scaling dialog in the Windows editor.



I applied the same scale factor to both circuits and found that I got significantly different values given the same light level (both covered with the foam cup). To adjust for component differences, I tweaked the scaling factor of the second "eye" circuit until both sensors returned the same value under the same lighting.

Okay, let's look at the code:

```
Read_Eyes:
  POT EyeL, 145, lfEye
  POT EyeR, 175, rtEye
  DEBUG CLS, lfEye, CR, rtEye, CR

Check_Eyes:
  IF lfEye = 0 AND rtEye = 0 THEN Is_Dark
  IF rtEye < lfEye THEN Is_Right

Is_Left:
  move = %10
  IF lfEye = 0 THEN Eyes_Done
  lfEye = rtEye - lfEye
  IF lfEye >= Threshold THEN Eyes_Done
  move = %00
  GOTO Eyes_Done

Is_Right:
  move = %01
  IF rtEye = 0 THEN Eyes_Done
  rtEye = lfEye - rtEye
  IF rtEye >= Threshold THEN Eyes_Done
  move = %00
  GOTO Eyes_Done

Is_Dark:
  move = %11

Eyes_Done:
  RETURN
```

The code starts by reading each "eye" into its own variable and displaying the readings in the DEBUG window. Then we check to see if both values are zero; this will happen in total darkness (due to the POT function timeout) or when both photocells are swamped with light. In either, case we want the robot to hold still. Setting the move variable to %11 tells our main code that this is the case.

Under most conditions, we'll have at least one photocell reading, so we do a comparison to see which side is getting the most light (it will have the lowest value). Let's assume that the left photocell had a lower reading and go through that section of code. The code for the right side works identically.

We'll assume that the threshold is going to be exceeded and preset the move variable to left (%10). Next, we check the value of the left photocell. If it's zero (swamped), there is no need to check the threshold and we can exit. If it is not swamped, we will subtract the right photocell reading from the left and compare the result against the threshold. If the threshold is exceeded, we exit, otherwise the move variable is set to forward (%00). Since this is a demo program, we should have some code to show us what's happening with the sensors. Here's a short bit of code to do that:

```
Main:
  GOSUB Read_Eyes
  BRANCH move, (Go_Straight, Go_Right, Go_Left,
Stay_Still)

Go_Straight:
  DEBUG "Straight"
  GOTO Main

Go_Right:
  DEBUG "Right"
  GOTO Main

Go_Left:
  DEBUG "Left"
  GOTO Main

Stay_Still:
  DEBUG "Holding..."
  GOTO Main
```

There's no magic here, we're simply using **BRANCH** to jump to code that will display the direction of robot travel. This lets us test our "robot eyes" on a breadboard. Bend the photocell leads so that they're oriented on the horizontal plane, and then turn them out from each other to expand the field of view. By shining a flashlight spot in front of the photocells, the **DEBUG** window will show the robot's movement behavior.

All that's left to do is replace the **DEBUG** statements with appropriate motor controls (and you know how to do that) to create a robotic photovore — kind of like an electronic kitten (cats love to chase flashlight spots), only this one won't scratch furniture or need a litter box!

Well, I told you we'd take it easy this time, and hopefully you agree with me that this was no less fun that we usually have. Modifying an existing motorized toy is a great way to get kids into robotics — no matter what their age.

Until next time, Happy Stamping. **NV**

EDUCATION KIT FOR CLOSED-LOOP CONTROL

The Flextek Education Kit is a low-cost system that provides an intuitive feel to closed-loop control while demonstrating Visual Basic programming, SPICE simulation, PIC micro familiarization, and general electronic principles. The kit includes a PC-based controller with mating infrared experiment board, closed-loop control software with tutorial and application notes, serial data cable, and power adapter. Visual Basic code demonstrates variable gain Proportional-Integral control of an IR emitter-sensor pair with strip chart for stability evaluation. The IR circuit reacts to external light or shadowing and has visual LED feedback to provide an intuitive "touch and feel" for experiments. The digital controller is converted to an equivalent analog circuit for loop-gain simulation in SPICE to gain a clear understanding of critical principles. Schematics suggest additional experiments for motion, thermal, and lighting control.

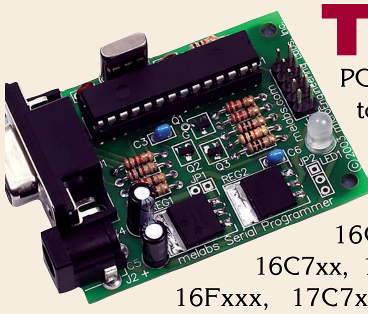
After experimentation, the controller is suitable for a variety of industrial tasks powered by a free Active X Control. The Flextek Education Kit FCED010 is available now from Flextek Electronics for $99.50 each at their website.

For more information, contact:

FLEXTEK ELECTRONICS
315B Walnut Ave.
Carlsbad, CA 92008
760-224-7637 Fax: **425-491-5601**
Email: **djcaldwell@flex-tek.com**
Web: **www.felx-tek.com**

Circle #117 on the Reader Service Card.

THE NEW SERIAL PROGRAMMER



The new meLabs Serial Programmer connects to a PC serial port and allows you to program most PIC microcontrollers, including the PIC12Cxxx, 12CExxx, 12Fxxx, 14000, 16C43x, 16C505, 16C55x, 16C6xx, 16C7xx, 16C84, 16C92x, 16CE62x, 16Fxxx, 17C7xx, 18Cxxx, and 18Fxxx devices.

The programmer is designed with in-circuit

programming in mind. It features a convenient 10-pin header that can be connected to a target board. This allows you to update a PIC's memory without removing the device from the board. This speeds the development process and allows you to program a surface mount device that is soldered in place.

The programmer isn't limited to in-circuit operation. A large selection of adapters is available for programming individual PICs. The programmer is available with accessories, including an adapter for 8-pin through 40-pin DIP packages. Optional ZIF adapters support surface-mount and PLCC devices with up to 80 pins.

Windows software is included with the programmer. It accepts standard Microchip format .HEX files that are generated by MPLAB, C compilers, and BASIC compilers. Command line options allow the programmer to be controlled from a batch file or shortcut for production use.

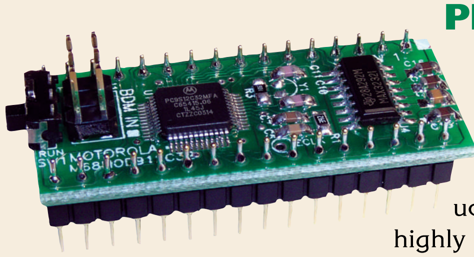
The software is loaded with selectable options, allowing you to customize your interaction with the programmer. A detailed memory view shows you each section of the memory in the PIC. The PIC's configuration bits can be set with convenient dropdown selections. The list of configuration settings is updated automatically when you select a device, so the list you see is tailored to the PIC you are programming.

The meLabs Serial Programmer with accessories retails for $119.95. This includes the programmer board, software, ZIF adapter for 8-pin through 40-pin PICs, AC power adapter, and 9-pin serial cable.

MICROENGINEERING LABS, INC.
PO Box 60039
Colorado Springs, CO 80960
719-520-5323 Fax: **719-520-1867**
Web: **www.melabs.com**

Circle #140 on the Reader Service Card.

LOW-COST MC9S12C32 MCU MODULE DOUBLES AS EVALUATION/TRAINING PLATFORM



Technological Arts has launched two new MCU products, broadening its highly popular line of

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modular microcontroller boards.

Offering engineers and educators a versatile and economical platform for evaluating and applying Motorola's latest HCS12 microcontroller offering, M68MOD912C32 and M68DKIT912C32 smooth the migration path from development to product implementation/production. Because the same core module used in the evaluation phase is economical enough to be incorporated into the end product, time to market for commercial applications is shortened considerably. Motorola has built the MC9S12C MCU family with a high-speed, low-voltage 16-bit core, up to 4K RAM, up to 128K sector-erasable flash, along with an array of hardware subsystems — all in a low-cost surface-mount package.

The 9S12C32 contains an asynchronous serial communications interface (SCI), a serial peripheral interface (SPI), an 8-channel 16-bit timer module (TIM), a 6-channel 8-bit Pulse Width Modulator (PWM), an 8-channel, 10-bit analog-to-digital converter (ADC) and a CAN 2.0 A, B software-compatible module (MSCAN12). The subsystems, together with the on-chip single-wire Background Debug Module (BDM), make this chip ideal for use in the evaluation and development of all "C"-series derivatives of the 9S12 family.

The M68MOD912C32 MCU Module implements the 48-pin version of the MCU. Combining all the essential MCU support circuitry with a small-footprint monitor/loader program in Flash, this module comes ready-to-use "out of the box" with little added hardware required in many applications. The MCU Module, designed in a standard 32-pin DIP footprint, includes the following features: 5-volt regulator, 8 MHz crystal, PLL circuit, RS232 transceiver circuit, and standard 6-pin BDM connector.

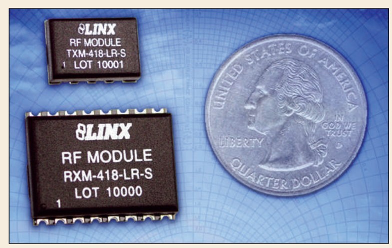
To facilitate evaluation of the 9S12C32 MCU, several product bundles are being offered. An MCU Module package — including MC9S12C32 MCU Module, user manual, Metrowerks CodeWarrior™ HC(S)12 version 4.0 CD, and resource CD — is available for $24.95(USD) (M68MOD912C32). A Demo Kit — including MC9S12C32 MCU Module, Demo Docking Board, CDs, Serial Cable, and DC power supply — is available for $49.95 (USD) (M68DKIT912C32). There is also a European version, which includes a universal power supply, for $64.95 (USD) (M68DKIT912C32-E).

For more information, contact:

TECHNOLOGICAL ARTS
877-963-8996 Fax: **416-963-9179**
Web: **www.technologicalarts.com**

Circle #135 on the Reader Service Card.

WIRELESS MODULES DELIVER LONGEST-RANGE AND LOWEST COST



The new LR Series of RF modules from Linx Technologies provides a 5-0 times range improvement over previous discrete

and modular solutions, thereby establishing a new range benchmark among comparable products.

These tiny SMD modules provide a complete and cost-effective solution for the wireless transfer of serial data, control, or command information over distances in excess of 3,000 feet.

No external components are required (except an antenna), allowing for easy design integration, even by engineers without previous RF experience. The modules interface to virtually any data source, including microcontrollers and decoder chips, making them ideal for applications, such as remote control, keyless entry, and periodic data transfer.

LR Series modules operate in the favorable 260-470 MHz band, and are designed for full regulatory compliance and interference immunity, ideally suiting them to domestic, as well as export wireless applications.

The modules operate over a 2.7-5.2 VDC range and feature low power consumption, (5.2 mA operational, 28 μA sleep), a wide operational temperature range (-40° to +70° C), adjustable transmitter power, and a receiver sensitivity in excess of -5 dBm.

A precision-crystal locked PLL architecture allows for transparent data transfer at rates of up to 10 kbps.

The LR Series is in full production and priced at approximately $3.58 (TX) and $6.78 (RX), in volume production quantities. Visit Linx Technologies' website for more on this product.

For more information, contact:

LINX TECHNOLOGIES, INC.
575 SE Ashley Pl.
Grants Pass, OR 97526
800-736-6677
Fax: **541-471-6251**
Web:
www.linxtechnologies.com

Circle #125 on the Reader Service Card.

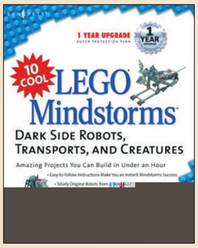
Selected Titles for the Electronics Hobbyist and Technician—

The *Nuts & Volts* Hobbyist Bookstore

Robotics

10 Cool LEGO Mindstorms: Dark Side Robots, Transports, and Creatures

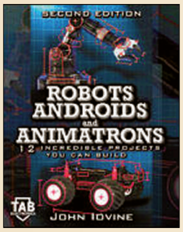
by Kevin Clague / Søren Rolighed / Miguel Agullo / Hideaki Yabuki



Okay, you bought the kit for yourself or one of your kids. You used the instructions in the box to build a robot or two. Now what? You may not be ready to design and build your own robots, but you don't want to build the same robot over again. This book is the perfect way to build additional projects from the same kit, then improvise and design your own. Ten cool projects — one hour each — perfect! **$24.95**

Robots, Androids, and Animatrons, Second Edition

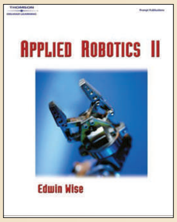
by John Iovine



In *Robots, Androids, and Animatrons, Second Edition,* you get everything you need to create 12 exciting robotic projects using off-the-shelf products and workshop-built devices, including a complete parts list. Also ideal for anyone interested in electronic and motion control, this cult classic gives you the building blocks you need to go practically anywhere in robotics. **$19.95**

Applied Robotics II

by Edwin Wise



Instructive illustrations, schematics, part numbers, and sources are also provided, making this book a "must" for advanced builders with a keen interest in moving from simple reflexes to autonomous, AI-based robots. Create larger and more useful mobile robots! Ideal for serious hobbyists, *Applied Robotics II* begins by discussing PMDC motor operation and criteria for selecting drive, arm, hand, and neck motors. **$41.95**

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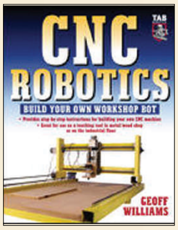
CNC Robotics

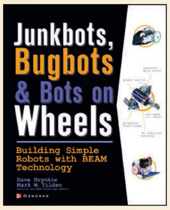
by Geoff Williams



CNC Robotics gives you step-by-step illustrated directions for designing, constructing, and testing a fully functional CNC robot that saves you 80% of the price of an off-the-shelf bot — and can be customized to suit your purposes exactly, because you designed it. Written by an accomplished workshop bot designer/builder. **$34.95**

JunkBots, Bugbots, and Bots on Wheels: Building Simple Robots With BEAM Technology

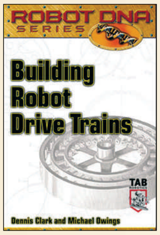
by David Hrynkiw / Mark Tilden



Ever wonder what to do with those discarded items in your junk drawer? Now, you can use electronic parts from old Walkmans, spare remote controls, and even paper clips to build your very own autonomous robots and gizmos. Get step-by-step instructions from the Junkbot masters for creating simple and fun self-guiding robots safely and easily using common and not-so-common objects from around the house. Using BEAM technology, ordinary tools, salvaged electronic bits, and the occasional dead toy, construct a solar-powered obstacle-avoiding device, a mini-sumo-wrestling robot, a motorized walking robot bug, and more. Grab your screwdriver and join the robot-building revolution! **$24.99**

Building Robot Drive Trains

by Dennis Clark / Michael Owings



This essential title is just what robotics hobbyists need to build an effective drive train using inexpensive, off-the-shelf parts. Leaving heavy-duty "tech speak" behind, the authors focus on the actual concepts and applications necessary to build — and understand — these critical force-conveying systems. **$24.95**

Everything you need to build your own robot drive train:

* The Basics of Robot Locomotion
* Motor Types: An Overview
* Using DC Motors
* Using RC Servo Motors
* Using Stepper Motors
* Motor Mounting
* Motor Control
* Electronics Interfacing
* Wheels and Treads
* Locomotion for Multipods
* Glossary of Terms/Tables, Formulas

The Robot Builder's Bonanza

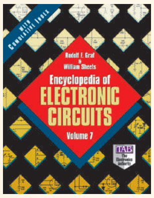
by Gordon McComb

A major revision of the bestselling "bible" of amateur robotics building — packed with the latest in servo motor technology, microcontrolled robots, remote control, Lego Mindstorms Kits, and other commercial kits. **$24.95**

Electronics

Encyclopedia of Electronic Circuits, Volume Seven

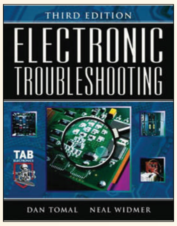
by Rudy Graf



Designed for quick reference and on-the-job use, the *Encyclopedia of Electronic Circuits, Volume Seven*, puts over 1,000 state-of-the-art electronic and integrated circuit designs at your fingertips. This collection includes the latest designs from industry giants such as Advanced Micro Devices, Motorola, Teledyne, GE, and others, as well as your favorite publications, including *Nuts & Volts*! **$39.95**

Electronic Troubleshooting

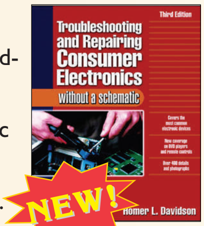
by Daniel Tomal / Neal Widmer



If you work with electronics — either through your profession or your pastime — here's one resource you need handy at all times: the updated, Third Edition of McGraw-Hill's *Electronic Troubleshooting*. Revamped to include the latest electrical and electronic devices and problem-solving methods, this information-packed volume provides a fundamental understanding of electronic troubleshooting theory. **$49.95**

Troubleshooting & Repairing Consumer Electronics Without a Schematic

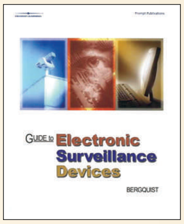
by Homer Davidson



In this book, Homer Davidson gives you hands-on illustrated guidance on how to troubleshoot and repair a wide range of electronic products — when you can't get your hands on the schematic diagrams. He shows you how to diagnose and solve circuit and mechanical problems in car stereos, cassette players, CD players, VCRs, TVs and TV/VCR combos, DVD players, power supplies, remote controls, and more. **$34.95**

Call 1-800-783-4624 today! or order online at www.nutsvolts.com

Guide to Electronic Surveillance Devices
by Carl Bergquist



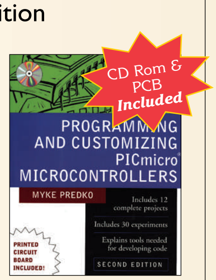
Enjoy the peace of mind that comes from knowing how to set up and maintain an effective surveillance system! Perfect for do-it-yourselfers, *Electronic Surveillance Devices* contains all of the information needed to enhance the safety and security of a home or office, from safeguarding against theft to monitoring employee performance and preventing illegal activities from occurring on site. **$35.95**

The Audiophile's Project Sourcebook: 120 High-Performance Audio Electronics Projects
by G. Randy Slone

The Audiophiles Project Sourcebook is devoid of the hype, superstition, myths, and expensive fanaticism often associated with high-end audio systems. It provides straightforward help in building and understanding top quality audio electronic projects that are based on solid science and produce fantastic sound! **$29.95**

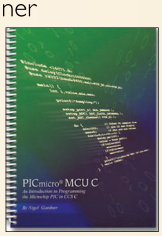
Microcontrollers

Programming & Customizing PICmicro Microcontrollers, Second Edition
by Myke Predko



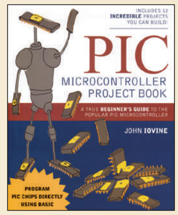
This book is a fully updated and revised compendium of PIC programming information. Comprehensive coverage of the PICMicro's hardware architecture and software schemes complement the host of experiments and projects making this a true "learn as you go" tutorial. **$49.95**

PICmicro MCU C
by Nigel Gardner



This second edition book is a complete introduction to programming Microchip PICmicros in C with the use of the CCS C compiler. The book overviews the ease of using C and the CCS compiler for optimization of your programming. There are many examples to get you started on while using the compiler. **$29.95**

PIC Microcontroller Project Book
by John Iovine

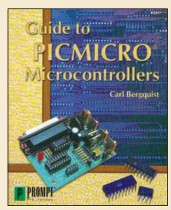


This project-oriented guide gives you 12 complete projects, including: using transistors to control DC and AC motors, DTMF phone number loggers, distinct ring detector and routers, home automation using X-10 communications, digital oscilloscopes, simulations of fuzzy logic and neural networks ... and many other applications. **$29.95**

Programming and Customizing the OOPic Microcontroller
by Dennis Clark

If you're a robotics professional or hobbyist, here's the one book you'll need to keep your work on the leading edge — *Programming and Customizing the OOPic Microcontroller*. This is the official OOPic Handbook, fully endorsed by Savage Innovations, the world's only manufacturer of OOPic microcontrollers. As the first book of its kind, this volume is destined to become the standard against which all other OOPic books will be judged. **$39.95**

Guide to PICMICRO Microcontrollers
by Carl Bergquist



Aimed at both students and seasoned users, this book will take the reader through the peripheral interface controller (PIC) like no other text. Hardware and software are also discussed in detail. Topics include: physical appearance, electrical structure, software requirements, hardware requirements, prototype layout boards, simple PIC programmers, PIC instruction set, use of the Microchip tools including MPLAB and Technical Library, software applications, software codes, and 8-10 PIC projects. **$45.95**

STAMP 2: Communications and Control Projects
by Thomas Petruzzellis

With the help of detailed schematics, informative photos, and an insightful CD-ROM, *STAMP 2 Communications and Control Projects* leads you step by step through 24 communications-specific projects. As a result, you'll gain a firm understanding of Stamp 2 and its programming methodologies — as well as the ability to customize it for your own needs and operating system. **$29.95**

The *Nuts & Volts* of BASIC Stamps, Volumes 1-4

$9.95 Volume 3

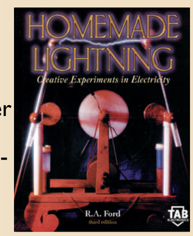
$14.95 Volume 4

$49.95 All 4 Volumes

In 1995, Scott Edwards began authoring a column on BASIC Stamp projects in *Nuts & Volts Magazine*. The column quickly became a favorite of *Nuts & Volts* readers and continues today with Jon Williams at the helm. *The Nuts & Volts of BASIC Stamps* is a four-volume collection of over 100 of these columns.

High Voltage

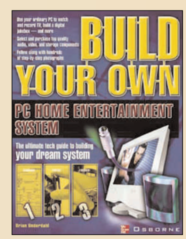
Homemade Lightning: Creative Experiments in Electricity
by R.A. Ford



Enter the wide-open frontier of high-voltage electrostatics with this fascinating, experiment-filled guide. You'll discover how to make your own equipment, how electricity is used in healing, and how many experiments in high potential physics work! **$24.95**

Home Entertainment

Build Your Own PC Home Entertainment System
by Brian Underdahl



Learn to use PC DVD drives, DVD recorders, and massive hard drives to create a home entertainment system that's comparable to what you'd enjoy from expensive, individual components. Who needs the movies? Now, you can achieve stunning audio and top quality video results through your PC. This book shows you how to build your own home entertainment center using an ordinary PC. Watch and record TV shows and movies, put your entire CD collection on your hard drive, and listen to radio stations from around the world. **$24.99**

If you don't see what you need here, check out our on-line store at **www.nutsvolts.com** for a complete listing of the titles available.

Hobby Electronics Is

Hobby electronics is often described as in decline. Sales of books and electronic parts aimed at the hobby electronics market have fallen. High school science fairs once included a fair number of electronics projects. Now such projects are scarce. RadioShack once sold hundreds of thousands of hobby electronics books a year. Now they sell none.

In view of these developments, is there a future for hobby electronics? The evidence shows that there clearly is. Before I explain why, let's turn the clock back a generation or so and review the evolution of hobby electronics.

From the 1950s to the 1970s, electronics hobbyists built light-controlled relays, solar batteries, tiny radios, and many kinds of electronic games long before such gadgets were sold in stores. This provided a terrific incentive for both teens and adults to become interested in do-it-yourself electronics.

The arrival of inexpensive TTL and CMOS integrated circuits in the early 1970s greatly expanded the horizons for electronic hobbyists. Now we could build counters, clocks, timers, and controllers that were far more sophisticated than basic transistor projects. Hobby electronics was at its peak, and the electrical engineering departments of colleges and universities could count on having many students who had learned the basics before they arrived on campus.

The arrival of Intel's 8080 microprocessor had far more impact on hobby electronics than the transistor and the integrated circuit. Now hobbyists could build their own computers, the ultimate do-it-yourself project. They didn't even have to design the machine, for they could buy a complete kit for $395.00 from MITS, Inc., a small company in Albuquerque, New Mexico.

The MITS Altair 8800 was featured on the cover of the January 1975 issue of *Popular Electronics*. The article attracted the attention of two young computer enthusiasts, Paul Allen and Bill Gates. Allen and Gates soon moved into the MITS building in Albuquerque, where they established a software company to develop BASIC for the Altair. They named their company Microsoft.

From 1975 to the mid-1980s, eager hobbyists built many kinds of gadgets and circuits for their computers to control. Hundreds of books described do-it-yourself computer projects.

Yet the hobby computer era was a bubble, not a trend. As more and more companies entered the computer market, there soon came a time when it was no longer practical to offer kit computers. The hobby electronics magazines eventually fell victim to the computer era to which they gave birth.

So where does this leave hobby electronics today? Our numbers have declined, but the quality

Down . . . NOT OUT!

of hobby electronics today is as high as ever. The old hobby electronics magazines have been replaced by a magazine with consistently high quality projects and articles. I feel the same sense of excitement opening up the latest issue of *Nuts & Volts* as I did back in the 1970s when I was writing articles and columns for *Popular Electronics*.

The sharp decline in electronics projects at science fairs and the declining enrollment in engineering courses at colleges and universities are troubling. But hope has arrived in the form of hobby robotics. Just a few weeks ago, my daughter Sarah participated in a high school robotics competition. The students learned a great deal about basic electronics and mechanics from the experience.

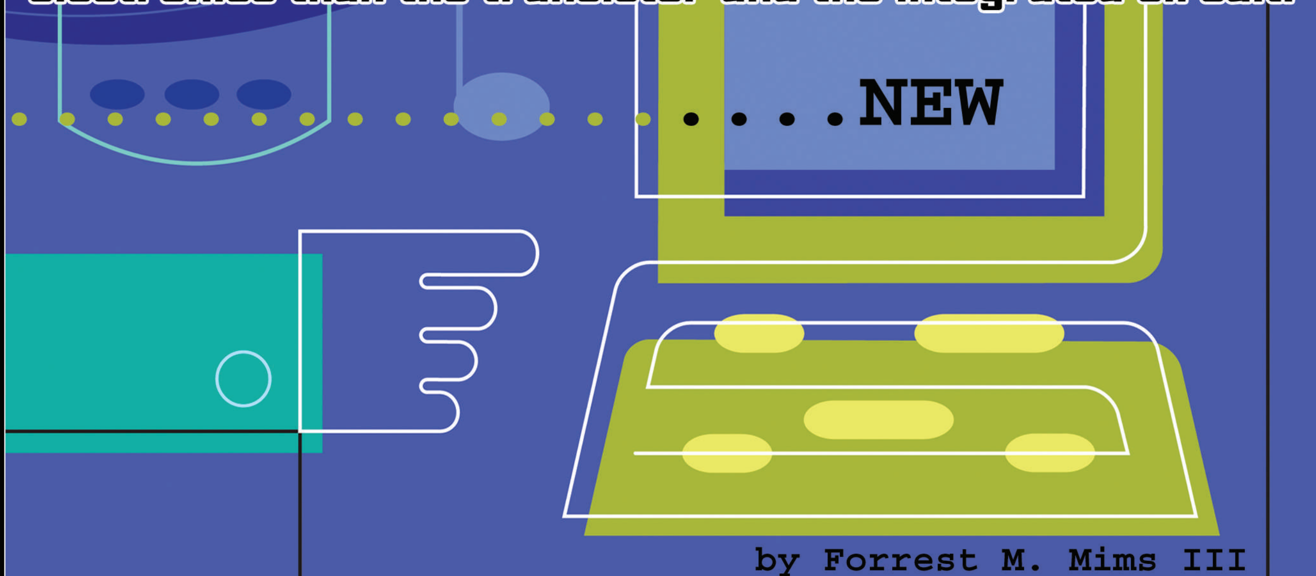
The overall number of electronics hobbyists was sharply reduced by the personal computer revolution they helped bring about. Yet there remain plenty of electronics enthusiasts who still enjoy designing and building circuits even more powerful and versatile than those we built a decade ago. Many hobbyists use computers to program their projects, which these days include many highly creative robotic devices. Others have found specialized niches for their electronics pursuits. In my case, for example, I design and use various instruments that measure the ozone layer, haze, and ultraviolet. Some of my inexpensive instruments have found errors in data from four remote sensing satellites.

So while the overall number of electronics hobbyists has declined since the 1980s, there are still plenty of fun, creative, and even scientific things that we hobbyists can do. Thanks to mail order suppliers like Digi-Key and Jameco, we can order virtually any electronic parts we need. And thanks to eBay and other web resources, we can buy high quality test equipment at only a fraction of the price we might have paid a decade ago. We can build lasers, radio-controlled electric aircraft, seismometers, and optical fiber communication links.

As for the future, I still remember the hundreds of excited spectators and participants who filled a large gymnasium during the recent robotic competition in which my daughter participated. These competitions are occurring all around the US, and the number of students who have built radio-controlled "robots" is probably far greater than those who built their own computers back in the 1970s.

So while hobby electronics lost many of its enthusiasts to the computer revolution it helped begin, there's still plenty to do for those of us who enjoy designing, soldering, tinkering, and programming. Just imagine the possibilities. Maybe some clever hobbyists can show the high school robotics movement how to build remotely piloted, indoor helicopters that score points by flying figure-8s and dropping plastic rings onto poles. **NV**

electronics than the transistor and the integrated circuit.



. . . NEW

by Forrest M. Mims III

About the Author *Forrest M. Mims III, an active member of the Society for Amateur Scientists (**www.sas.org**), develops lab kits for RadioShack when he is not doing professional science. His electronics books have sold some 7.5 million copies. Visit him on the web at **www.forrestmims.org***

by Dan Shanefield

Harvesting Electricity From The Environment

Light a 100 Volt Bulb with the Waves that Surround You

This Month's Projects

Harvesting Electricity . .40
Capacitance Meter . . 43
Membrane Switches . 48
Blackbox Frisbee 52

The Fuzzball Rating System

To find out the level of difficulty for each of these projects, turn to Fuzzball for the answers.

The scale is from 1-4, with four Fuzzballs being the more difficult or advanced projects. Just look for the Fuzzballs in the opening header.

You'll also find information included in each article on any special tools or skills you'll need to complete the project.

Let the soldering begin!

With "smart" cell phones, Wi-Fi, RFID tag systems, and so many other new applications for radio waves these days, it is obvious that we are immersed in an electromagnetic field ("EMF") just about everywhere we go. Whether or not this is harmful to human beings is a controversial subject, although many scientists will tell you it is not hurting us at the present intensity level. However, you can easily demonstrate that such fields can be pretty strong. At the very least, this indicates an ever increasing need for shielding in hobby electronics projects, to avoid picking up troublesome noise.

Because there is so much EMF in the general environment, several research projects (mostly military) are purposely "harvesting" the energy and trying to use this to operate sensors, tiny transmitters, and other devices that will never require batteries or even solar cells. Another branch of the research aims to use strictly mechanical noise to harvest energy from the environment, similar to the way a self-winding mechanical wristwatch operates. However, many useful things such as sensors need electric power in some way, and it is usually inefficient to collect low-level mechanical energy and convert it to electricity.

Although a radio aerial converts electromagnetic waves into electricity, the voltages that are fed to cell phones from ferrite antennas are typically only a few microvolts. It might be a surprise to the reader, but a million times more voltage — possibly four volts or so — can actually be harvested by simple means from many common environments, by using a fairly long antenna and a good ground. The currents are small, but they can easily be accumulated, enough to briefly light a Tungsten incandescent bulb. With a transformer, these voltages can be stepped up enough to flash a neon bulb. It's amazing, but quite true, and all this can be verified with experiments that are easy to do.

The Experimental Set-up

The circuit is shown in Figure 1, but it is not necessary to use any actual switches. Alligator clips could be used instead. For example, looking at S1 in the diagram, a clip lead could be temporarily connected from the

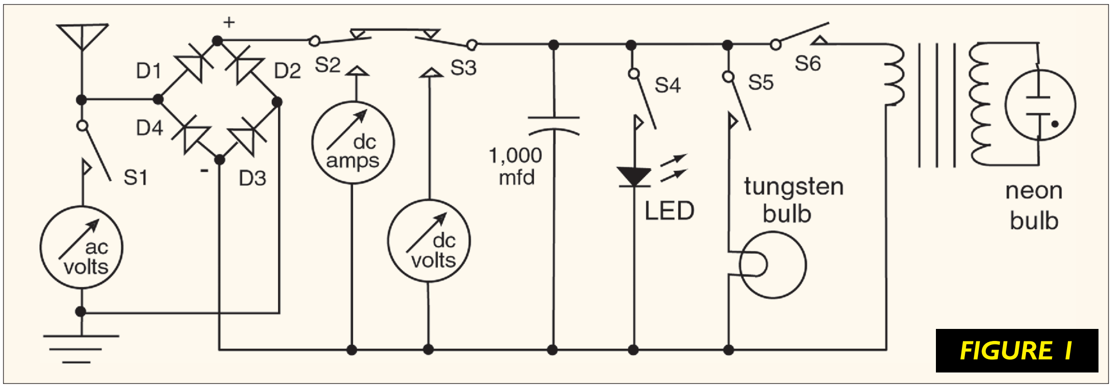


FIGURE 1

antenna to the AC voltmeter.

For the antenna, a 15-foot-long extension cord can be used, or any other insulated wire of roughly that length. For the first experiments, it can be stretched out on the floor of your home, maybe extending into another room.

A "quiet" ground is needed, to avoid picking up stray voltages that are not electromagnetic in origin. It should be noted that the "return" or "neutral" wire of 120 volt AC power lines (color coded white in the US) is not suitable, because it often has considerable voltage on it, due to resistive ground connections. Using that would be cheating, if we are investigating the power that comes strictly from EMFs in the air. Similarly, the green coded safety connection might have about 10 volts on it — relative to true ground — if a clothes dryer or air conditioner is running nearby. For these experiments, a better ground connection can be obtained by hammering a bare metal curtain rod into the earth and attaching a clip lead to it.

The meter to measure the AC voltage can be any instrument with an input impedance of around 10 megohms, such as a portable digital multimeter. This could also be used to serve as the ammeter and DC voltmeter shown in Figure 1, if it is disconnected from position S1 and then reconnected at S2, and later at S3. Alternatively, of course, separate meters could be used.

A full wave diode bridge can rectify the input, as shown. However, good results can be obtained with just diode D1, with a plain wire in place of D3, and no connections at all in positions D2 and D4.

The LED should be a low current type, such as RadioShack catalog number 276-044, which will produce visible light with only two milliamps. The Tungsten incandescent bulb also has to be a low current type, such as RadioShack catalog number 272-1139 or similar, which will light up with only 20 mA. The transformer can be a step-down 120-volt to six-volt power supply type, which we will operate "backwards," in a 20:1 step-up mode. Switch S6 (or just an ordinary clip lead) is going to be used to dump the capacitor's charge into the low voltage winding, and almost any neon or argon lamp attached across the high voltage winding will then flash.

The Waves that Surround Us

Unless you are down in an iron mine, you are probably in a measurably strong electromagnetic field. Even inside a metal building, there is usually some oscillating field coming from the 120-volt AC power lines in the walls, just because of the power that always goes to computers, "instant-on" TV sets, and even the multiplicity of electric

PARTS LIST	
Insulated wire	15 or 20 feet long (for antenna)
Metal rod	(for ground connection)
Diode	Or full wave rectifier bridge
Capacitor	1,000 µF or similar
Multimeter	10 megohm input impedance
Clip leads	Or 3 SPST and 3 SPDT switches
2 mA LED	Like RadioShack 276-044
25 mA bulb	Like RadioShack 272-1139
Transformer	20:1 or similar
Misc.	A small neon or argon bulb

clocks that are in most people's houses. This is especially true in an urban or suburban area, if there are power lines up on telephone poles near the house — the amount of EMF radiation that they generate might surprise you. At any rate, you can sense such fields with the apparatus of Figure 1 and judge for yourself.

Inside a typical house or office building, quite a lot of our environmental EMF is 60 Hz AC or harmonics of it. Weaker radiation is at the extra-low frequencies generated by thunderstorms all throughout the world, as readers of *Nuts & Volts* already know from the article "DX Thunderstorms in Africa" in the October, 2003 issue (page 44). A wide variety of radiation is being suggested as sources of energy to be harvested, as described in the publications that any Internet web search engine will turn up, if you enter "harvest electricity" in the dialog box. However, more and more RF will be at microwave frequencies, as we make increased use of things like the RFID tags that Wal-Mart and other big businesses are putting in place by the millions, and as Wi-Fi gets into more public places and even into home networks.

A Few Measurements

With a 15 foot or longer antenna snaking along the floor from room to room in a typical suburban house, and using a grounding rod outside, you are likely to see from two to four volts of AC (RMS). Surprisingly, this might not vary much as a high current appliance such when a clothes dryer is switched on and off. Taking the antenna outdoors, draped horizontally over some beach chairs over a backyard lawn, you can expect a lower voltage, possibly only a few hundred millivolts. Arranging the antenna vertically up a tree, the measured voltage is not usually much different, in spite of the fact that many radio transmissions are vertically polarized. Moving the whole apparatus to a front yard, near power lines on telephone poles, the measurements are likely to be more like what is seen inside a house, possibly a few volts. On the other hand, in a rural setting, away from houses and power lines, the voltages are likely to be lower.

Looking at the input with an oscilloscope attached in place of the AC voltmeter of Figure 1, there might be a lot of 60 Hz content visible in the received signal. In some cases, there is much distortion of the basic sine wave, and there is more harmonic content than fundamental, particularly at 120 Hz, due to various phase delays. There is almost always a great deal of continuously varying, high frequency hash riding on top of the steadily repeating signals. Some of this is at extremely high frequencies and consists of digital pulses, even though the simplified antenna biases the apparatus towards picking up low frequencies.

From observations such as these, it can be seen that our electronic devices need good shielding against EMFs these days. Maybe the shields will have to be improved in the future, as more and more of these invisible fields become commonplace. In many cases, it is already necessary to use "guards" as well as "shields," for devices such as op-amps with very high amplification factors. (The difference between a shield and a guard is explained in a textbook I wrote, *Industrial Electronics for Engineers, Chemists, and Technicians*, William Andrew Publishing, 2001.) It also seems sensible to re-evaluate the possible effects on human beings from time to time, as these fields get more intense, and their frequencies go up.

Accumulating the Energy

With the attachment of a rectifier, DC can be stored in the 1,000 µF capacitor. The full wave diode bridge in the figure is efficient, but slower accumulation can be obtained with just D1, as mentioned above. By switching S2 (or just using a clip lead), the interrupted DC flow can be estimated, and typical readings inside a house might be (surprisingly!) as high as a few milliamperes, although a tenth of that is more common.

After approximately an hour of charging, the 1,000 µF capacitor voltage can be measured via S3. This will be the RMS AC voltage times the square root of 2, and four volts is typical when measured inside a suburban house. In an electrolytic capacitor, it is enough energy to light a low current LED, through S4. In fact, a brief flash can be visible in a low current Tungsten bulb, via S5.

Using S6 or the equivalent, the capacitor's charge can be suddenly dumped into the primary of a step-up transformer. (As mentioned above, a power transformer that is normally step-down can be used "backwards" for this experiment.) A ratio of 10:1 or 20:1 will usually light a small neon or other gas discharge bulb for an instant. On the oscilloscope, this pulse can register as high as 100 volts. Thus, a fairly high voltage can be harvested from our environment, by very simple means. **NV**

AUTHOR BIO

Dan Shanefield was a retired Bell Labs scientist, then became a Distinguished Professor at Rutgers University, and is now retired from that job, as well. You can visit his website at **http://homepage.mac.com/shanefield**

A Simple Capacitance Meter Using The ADuC812

Clever Programming Yields a Useful Bench Tool

There are many ways of measuring capacitance. In this article, I describe a simple method that makes use of the features of the ADuC812 one of Analog Devices MicroConverters®. The capacitance meter measures capacitances between 100 nF and 100 µF with ease. The capacitance meter sends the measured capacitance to a PC's COM port.

The MicroConverter

Before describing how I measure the capacitance, I would like to describe MicroConverters in general and the ADuC812 in particular. Analog Devices has a line of products that are essentially microcontrollers with data conversion peripherals on-board. They refer to this product line as MicroConverters. The ADuC812 (where ADuC stands for Analog Devices MicroConverter) is essentially an 8052 microcontroller with eight channels of A/D, two channels of D/A, and 8 Kbytes of FLASH program memory that can be programmed across a serial port. Other peripherals that I did not need for this project include user programmable FLASH memory, a watchdog timer, and a ninth channel of A/D that is connected internally to a temperature sensor.

In my experience, the ADuC812 is an excellent processor to work with, and you can have a lot of fun programming it. For this project, I used the EVAL-ADUC812QS development kit. This kit provides you with a nice interface to the ADuC812. It has a user controllable LED, pushbuttons, buffers for some of the inputs to the ADuC812, and many other helpful items. For those who would like to learn more about the ADuC812 and MicroConverters, Analog Devices MicroConverter page can be reached by going to **www.analog.com**, clicking on the "Data Converters" tab and then selecting the "MicroConverter" tab.

How I Measure the Capacitance

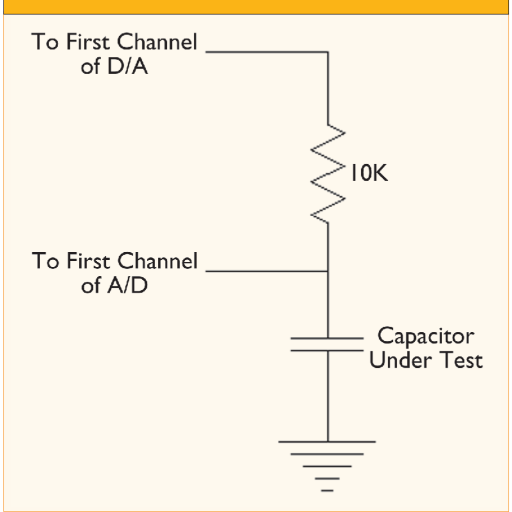
Measuring the capacitance is fundamentally simple. Connect the output of the first D/A converter to one side of a 10 KΩ resistor. Connect the other side of the resistor to the capacitor under test. The point between the resistor and the capacitor is also connected to the first channel of the ADuC812's A/D converter. Finally, the second side of the capacitor is connected to the ADuC812's ground. (See Figure 1.) When the user indicates that s/he is ready to have a measurement taken, the ADuC812 raises the voltage at the output of the D/A to 2.5 V. At the same time, the ADuC812 starts one of its timers (a standard feature on all 8052s) going.

One of the modes in which the ADuC812's A/D converter can work is to sample every second time the timer overflows. I used this setting. From the point at which the D/A voltage goes to 2.5 V, the ADuC812 examines the voltage between the resistor and the capacitor every second time the timer overflows. Each time the A/D checks the value on the capacitor and the voltage is less than 1.25 V, a set of counters are updated. When the voltage on the capacitor reaches 1.25 V, the ADuC812 records the elapsed time from the time the voltage on the resistor went to 2.5V until the voltage on the capacitor reached 1.25 V.

As the voltage on a capacitor whose voltage was zero until, at t = 0, a voltage was applied follows the formula:

$$V_{cap}(t) = V_{applied}(1-e^{-t(RC)})$$

FIGURE 1. The RC circuit and its connections to the ADuC812.



The time that the capacitor takes to reach half of the applied value, $t_{1/2}$ is:

$$t_{1/2} = RC\ln(2)$$

As the MicroConverter has measured $t_{1/2}$ and R is known, it is easy to determine C. In fact:

$$C = \frac{t_{1/2}}{R\ln(2)}$$

Practical Matters

Fundamentally, this capacitance meter is easy to build. The devil is in the details. Calculating is no problem at all if you have a microprocessor that knows how to divide. Unfortunately, the 8052 barely knows how to multiply. To avoid the necessity of multiplying or dividing, I played a simple game. I set the timer to overflow every 0.0347 milliseconds. Thus, to overflow twice took the timer 0.0694 milliseconds. I had the microprocessor keep track of how many such periods went by from the time that 2.5 V was first applied to the resistor until the voltage on the capacitor rose to 1.25 V. (That is how the MicroConverter stores the elapsed time.) Let the number of periods that elapsed be N. Then, $t_{1/2} = 0.0694N$. Let us see what that says about C as a function of N. Plugging in the values we find that:

$$C = \frac{0.0000694N}{10000\ln(2)} = \frac{0.0000694N}{6931.5} \approx 10NnF$$

With the timer set like this, no calculations need to be done. The number of cycles determines the capacitance in a very simple way. In order for a measurement to be reasonably accurate, should be at least 10. In order that the measurements not take too long, should not be too large. I allowed up to 10,000. Thus, the capacitances for which this simple meter can be used range from 100 nF to 100 µF. The range can be adjusted by changing the value of the resistor.

The Physical Connections

In order to connect the resistor and capacitor to the correct pins on the development kit, you must know where each of the lines that is called for is physically located. The analog ground of the circuit is available in the prototyping area of the development kit on a strip labeled 'AGND.' For the A/D and the D/A connections, look for the ANALOG I/O connector on the development kit. This connector is clearly labeled and is located between LK1 and LK2. The first channel of the A/D (ADC0) is led off to the leftmost pin on the row of pins that is nearest to the edge of the development kit. The first channel of the D/A (DAC0) is led off to the third-to-last pin on that row of the ANALOG I/O connector.

Thinking Smarter — Not Working Harder

Many microcontrollers either do not support division or support division to a limited extent. And even when they do, it is often a time-consuming operation. In the case of 8051 type microcontrollers, division of two eight bit words takes four instruction clock cycles to execute. (Multiplication and division are the only operations that take so long.) To do 16 (or more) bit division takes more time and is more complicated.

When time needs to be measured, it is best to set up your time-base in a fashion that minimizes the need to use expensive or complicated operations. One operation that can often be simplified is the calculation of a quantity that depends directly on a measurement of time. In order to measure capacitance, we measure a time — $t_{1/2}$. We have seen that:

$$C = \frac{t_{1/2}}{R\ln(2)}$$

We want to make sure that the calculation of the capacitance is as simple as possible. Suppose that you check the voltage at the output of the RC filter every τ seconds. Then the first time for which the voltage is greater than half the input voltage is $t_{1/2} = N\tau$. Thus, the capacitance is:

$$C = \frac{\tau}{R\ln(2)}N$$

In order to avoid the need to perform any calculations, and to calculate the capacitance from N, you must choose the values of the resistor and the sampling time in such a way that:

$$\frac{\tau}{R\ln(2)}$$

is particularly "nice."

Suppose, for example, that you would like to measure capacitances that are between 1 µF and 1 nF. Ideally, you would like to have N be reasonably large, even for 1 nF. Let us suppose that we would like N = 10 when C = 1 nF. Then we find that:

$$1\times10^{-9} = \frac{\tau}{0.69315R}10$$

That is:

$$t = 6.9315\times10^{-11}R$$

On practical grounds, we do not want to choose odd resistor values, nor do we want to have to sample too often. Suppose that we take R = 1MΩ. Then, we find that $\tau = 6.9315\times10^{-5}$. Setting our sample rate to $1/\tau$ = 11,427 samples per second will do the trick. With this sampling rate and resistor value, the capacitance measured will be C = 10 NnF. Displaying such a value (as we do in the accompanying program for the ADuC812) is a triviality. We converts the number N into a string and then add a "0" to the end of the string. The string now holds the capacitance in nanofarads, and no calculation was performed.

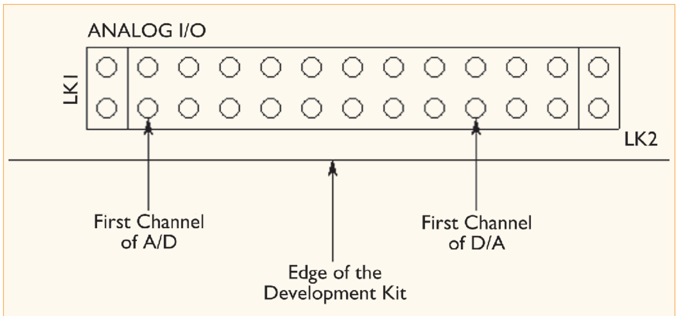


FIGURE 2. The location of the first channel of A/D and the first channel of D/A on the evaluation kit.

(Counting from the pin that connects to the first channel of the A/D, it is the ninth pin over.) See Figure 2.

The Serial Interface

When using the development kit, the serial interface is used for two purposes — downloading the program and communicating with the ADuC812 while the program is running. Downloading programs to the ADuC812 development kit is easy. First, connect the serial cable that comes with the kit to the kit itself (being careful to match up the pins on the board with the markings on the cable). Then connect the cable to COM1. (For some reason, the downloader that comes with the development kit does not seem to work from COM2.) Make sure that the jumper at location LK3 (PSEN) on the evaluation board is in. Run WSD, the Windows serial downloader. Go to the configuration menu of the downloader and make sure that it is set to COM1. Next click on DOWNLOAD. Find the program that you want to download and download it. Finally, click on the RUN button. At this point, the program is running on the ADuC812.

The program that is running on the ADuC812 expects to communicate with the outside world through the COM port, too. The program sets the ADuC812's internal UART to transmit and receive at 19200 baud with one stop bit and no parity bit. Additionally, no flow control is used. Thus, the host computer must be set up similarly. I generally use Hyperterminal (a Windows utility) to communicate with the ADuC812. When using Hyperterminal, you must tell Hyperterminal which COM port you are using (COM1), and then you must set the properties of the COM port to 19200 baud, one stop bit, no parity, and no flow control.

Once the set-up is taken care of, to initiate a measurement all that you need to do is to type a lower case 'm' in the Hyperterminal window. The ADuC812 will measure the capacitance and will send the capacitance value to the COM port. Hyperterminal will pick up the value and display it on your screen.

For those who do not want to type, the ADuC812 has been set to start a measurement when the INT0 button on the development kit is pressed. In order to see the value of the capacitance, you must still use Hyperterminal.

Programming the ADuC812

There is only one jumper on the evaluation board that I regularly use — the jumper at position LK3. When this jumper is in, resetting the ADuC812 causes the ADuC812 to wait for instructions to come to its UART. This jumper must be in when you want to send a new program to the ADuC812. After you load a program, it is possible to tell the ADuC812 to start running by sending the appropriate commands to the UART. This is what clicking on the RUN button does.

Recall that the program memory of ADuC812 is (non-volatile) FLASH memory. Even after turning off the processor, the program is still in the FLASH memory. If the jumper at LK3 is out, then when the ADuC812 is powered-up or reset, it does not wait for instructions to come from the UART. Rather, it jumps to the start of the program memory and starts executing the current resident program.

If you have already downloaded the capacitance meter program and reset the ADuC812 after setting up Hyperterminal, you will see that upon power-up the program clears the Hyperterminal screen and sends the computer the string "Hit 'm' to perform a measurement." (In fact, the messages that cause this to happen were sent when the RUN tab was hit the first time the program was run. At that point, however, there was no program running on the host computer to "listen" to what the ADuC812 "said.") Pressing “m” now will cause a measurement to be made.

A Cautionary Note

A word of caution is in order. After the MicroConverter finishes making a measurement, it resets the voltage on the D/A to 0 V. This allows the capacitor to discharge. If you have a fairly large capacitor, you must wait a second or two for it to drain completely. If you don't, the capacitor will not have completely discharged and the next measurement will be incorrect (too low). This is because the capacitor will not take as long to charge as it should — it started out partially charged.

Adding Bells and Whistles

I have presented a simple capacitance meter. It is relatively easy to extend this meter into a multimeter. Of course, doing so would increase the complexity of the meter and would take a fair amount of time. Enjoy! **NV**

Author Bio

Shlomo Engelberg received his B.E.E. in 1988, his M.E.E. in 1990, his M.S. (in mathematics) in 1991, and his Ph.D. (in mathematics) in 1994. He teaches electronics at the Jerusalem College of Technology-Machon Lev. In his spare time, Shlomo enjoys walking, reading, and playing with his children.

Circle #75 on the Reader Service Card.

by Gerard Fonte

Make Your Own Custom Membrane Switches

A Simple — Yet Effective — Way to Dress up Your Projects

Membrane switches are useful for a number of reasons. They're thin, water resistant, and can be customized. Unfortunately, custom set-up costs are high and take a lot of lead time. This article will show you how to make your own custom "pre-production" membrane switch quickly and at very low cost. There are many variations that you can do, so use this as a starting point and follow your imagination. Figure 1 shows the basic idea of how this works.

Figure 1. Here is the basic approach for the membrane switch. The paper overlay is protected with package sealing tape on the top, and attached to the front panel with double-sided tape on the bottom. The PCB is mounted with spacers so that the top of the switch actuator is even with the top of the front panel.

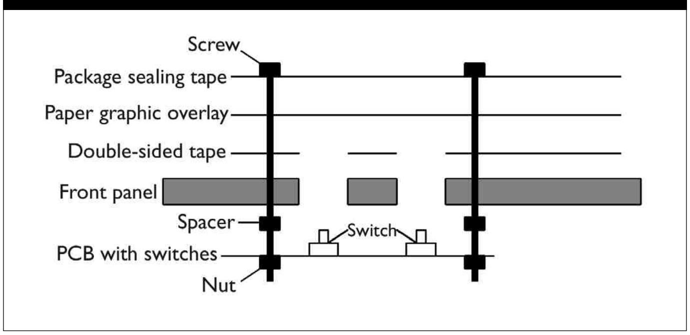
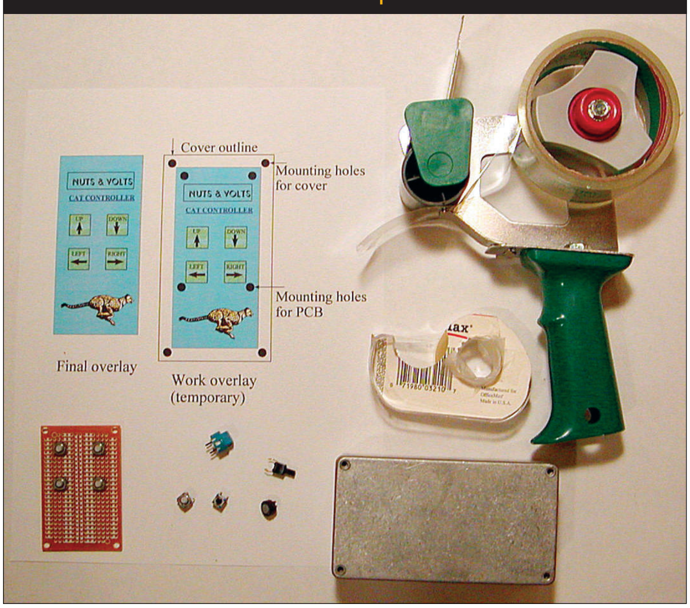


Photo 1. The basic parts needed.



What You Need

Photo 1 shows the basic parts needed. The Printed Circuit Board (PCB) in the lower left has just four switches on it. These switches must be the very common "membrane" push-button type, but the housing can vary (more details on this later). Typical switches are shown to the right of the PCB. You will also need the overlay graphics (upper left). This is just a piece of paper with whatever you want on it.

Obviously, the push buttons on the overlay must line up with the PCB switches. I also make a second "work overlay." This has the mounting holes for the PCB and front panel (lower right). This makes alignment much easier.

Generally, this paper overlay is created with whatever computer software graphics package you have. Although, you could do it by hand.

The "special" items you need are two-inch wide transparent package sealing tape and double-sided cellophane tape. Both of these are available at any office supply store. You don't really need the package sealing tape dispenser (about $20.00) but it makes things much easier. You'll also need basic hand tools and a drill (a drill press is much easier).

Drill the Front Panel

The first step is to drill the front panel with holes for the switches and mounting holes for the PCB. You need to provide good alignment between the overlay, front panel, and PCB. Photo 2 shows the paper work overlay attached to the front panel with a couple pieces of double-sided tape. The center points of the switches and mounting holes are center punched through the paper.

Note that the tape extends beyond the front panel.

This makes removing it easy. Also, this particular front panel is aluminum. If you use a plastic front panel, don't center punch too hard or else you'll break the plastic.

Photo 2. The paper work overlay is attached to the front panel with a couple of pieces of double-sided tape.

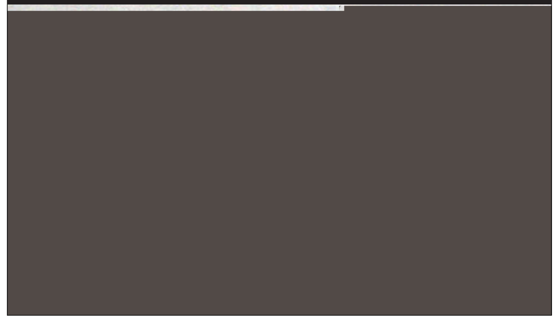


Photo 3. This shows the results — the PCB is temporarily mounted to the front panel and the work overlay has been removed.

Big Holes for the Switches

Photo 3 shows the results. The PCB is temporarily mounted to the front panel and the work overlay has been removed. Note that the switch holes are about 0.5-inch in diameter. This allows the switch body to extend part way through the front panel. (Be careful with shorts to a metal front panel.) If you use long actuator switches, still use about 0.5-inch diameter holes. This is because the overlay has to flex a little. Holes that are too small won't flex very well. You may want to experiment.

You will also have to adjust the spacing of the PCB so that the top of the switch actuator is just about level with the top of the front panel. In this case, a single nut provides the proper spacing.

Attaching the Overlay

Remove the PCB and put double-sided tape on the front panel. Use strips side by side, without any overlap. Be sure that this tape is wider and taller than the overlay — the excess will be trimmed off.

Again, extending the tape beyond the front panel makes trim removal easier. Remove tape from all openings in the front panel. An Xacto knife works well for this. See Photo 4.

Use the package sealing tape to cover the overlay — and be careful — this step shows any and all mistakes. (It's often worthwhile to have several spare paper overlays.) If the overlay is wider than the tape, you can either put the next strip side- by-side or overlap slightly (about 1/8-inch). If you overlap, try to place the seam away from switch openings.

Note, I find that putting tape on the overlay and then trimming/cutting the overlay to size from the paper easier than trying to put tape on an already trimmed-to-size overlay. If you have air bubbles, carefully pierce the paper to let the air out. Don't pierce the tape or else it will eventually tear there.

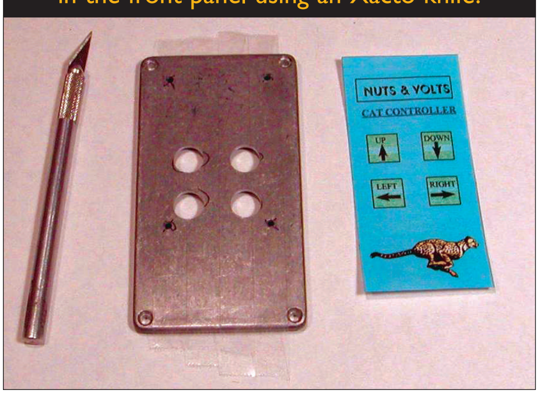


Photo 4. Remove tape from all openings in the front panel using an Xacto knife.

Carefully place the overlay on the front cover. This is the hardest part. You have to make sure that the alignment is perfect before you press down. If you try to move the overlay after it's stuck to the tape, it will almost certainly tear. I shine a bright light behind the front panel so that the holes shine through the overlay. This makes alignment easier. Once you are sure the alignment is correct, press the overlay down from the middle to the edges. There is no easy way to remove air bubbles.

Trim away the excess double-sided tape. This should look like Photo 5.

Final Assembly

Carefully cut through the overlay for the PCB mounting holes. Attach the PCB with the proper spacers. The membrane switch should now work (see Photo 6). You may want to experiment with the spacing to provide the switch feel you like.

Variations and Notes

This particular version had only the switches on the PCB. If you want to mount parts on the PCB, there are two basic ways to do that.

First, use tall actuator switches. This allows parts to be placed on the same side as the switches. This requires longer spacers and obviously limits the height of the parts. The second way is to put the parts on the "back" side of the PCB. However, in practice, it would be the switches that are mounted on the back of the PCB while the parts are on the front.

But what about LEDs or dis-

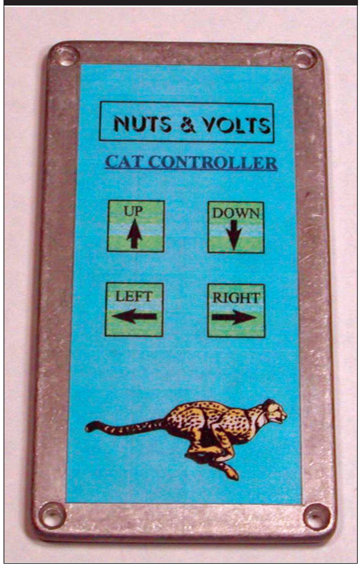


Photo 5. Trim away the excess double-sided tape.

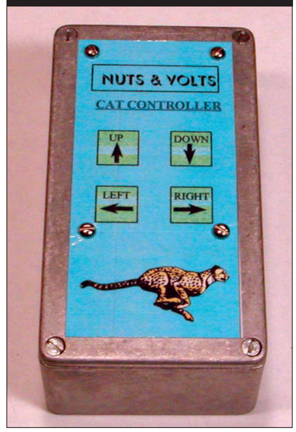


Photo 6. Carefully cut through the overlay for the PCB mounting holes. Attach the PCB with the proper spacers. The membrane switch should now work.

plays? Yes, windows are easy to make. Just remove the proper area on the paper overlay before applying the package sealing tape. This leaves a window with sticky tape on the inside face. Now, cut a piece of package sealing tape a little larger than the display opening. Carefully attach that to the inside of the window — sticky side to sticky side. No more stick! And the window will be very clear. (Watch out for air bubbles.)

Finally, PCB flex can be a problem. That is, the PCB flexes instead of the switch closing. This happens if there is too much distance from the switch to the PCB mounting holes. Usually this has to be more than an inch or two. The solution is to add a mounting hole closer to the switch. However, sometimes it is possible to get a switch that needs less pressure to close.

Conclusion

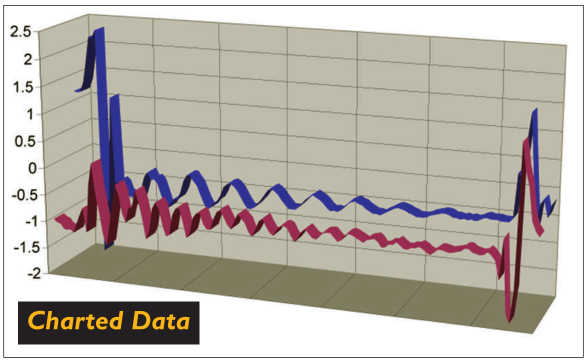
Attractive custom pre-production membrane switches can be fabricated quickly and cheaply using simple tools and materials. They are water resistant and can be quite thin. Custom switch set-up costs and lead times are eliminated — while giving your project that "pro" feel. **NV**

by Ralph Lorenz

The Amazing Frisbee Black Box or BASIC Stamp Frisbee

Instrument Your Favorite Sporting Goods!

Is it a bird? Is it a plane? No, it's a computerized Frisbee with a BASIC Stamp! In this simple project, I will show you how to make an ultralight, but easy-to-assemble, acceleration recorder that you can use to measure the dynamics of small vehicles, much like the "black box" aircraft flight recorders.



Charted Data

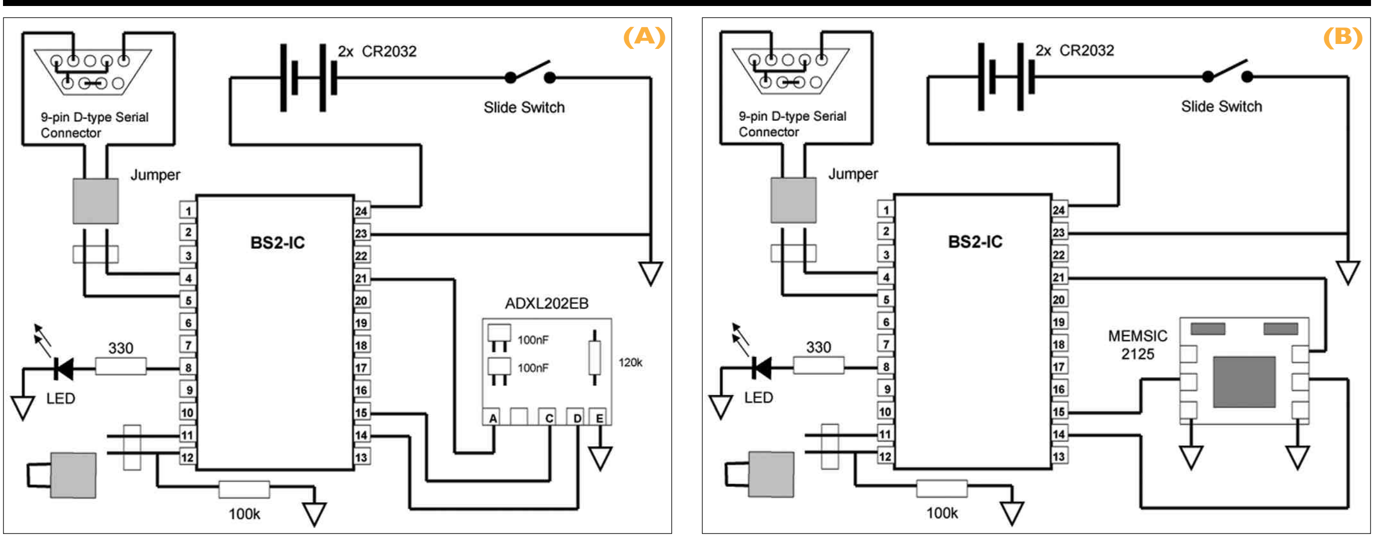
Frisbee Background

I wanted to understand the aerodynamics of a Frisbee by taking in-flight measurements of lift and drag. Although Frisbees (the name — a corruption of that of William Frisbie, a Connecticut baker whose pie tins formed the inspiration for flying disks — is a trademark of Wham-O, Inc.) are very familiar objects, their impressive flight performance is only documented with a handful of published studies and wind-tunnel measurements. Some background can be found at **www.discwing.com** and at **http://mae.engr.ucdavis.edu/~biosport/frisbee/frisbee.html**. By taking in-flight measurements, I would understand the changing aerodynamic forces throughout a free flight.

The challenge was to make a super-lightweight and compact instrument package. The accelerometer and the microcontroller were tiny enough, but the power supply presented a problem. Two lithium button cells (CR2032) in series can provide 6 V, but only about 10 mA of current. This is, however, just enough to run a BASIC Stamp II (although not enough to run other, faster microcontrollers like the BS2-SX or a BasicX-24.) The accelerometer draws just a few milliamps at most.

The circuit itself is very simple, as the accelerometer interfaces very easily with the microcontroller. Given 5 V, it spits out two square wave signals, which are pulse-width

Figure 1. Circuit diagram for the ADXL202 (A) and MEMSIC 2125 (B) accelerometer options.



modulated (PWM) by the acceleration in two axes. If it senses zero-g, if that axis of the accelerometer (there are two) is horizontal, or if the device is in free-fall, the duty cycle of the output is 50%. The duty cycle increases by 12.5% for each "g" of acceleration, up to two in each direction. So, all the circuit does is measure the pulse lengths on the two accelerometer axes, record those numbers, and read them out afterwards. Simple!

Choice of Accelerometer

The best device to use is the Analog ADXL202. The accelerometer itself is a tiny surface-mount device, but it is conveniently sold on an evaluation board. This unit used to be sold by Parallax (the makers of the BASIC Stamp), but they have replaced it in their catalog with a MEMSIC unit, which is a little smaller.

There are three big differences between these devices. The Analog device uses a bending beam to sense acceleration and can be tuned to optimize bandwidth against signal-to-noise (two 0.1 mF capacitors and a 120K resistor on the board set the pulse width and sensing bandwidth correctly for this application, the PWM period being about 1 ms), and draws only about 0.5 mA. The MEMSIC unit uses a different sensing principle, measuring the "gravity-driven" convection of heated air. It, therefore, has an intrinsically slower response, and draws more current — about 4 mA. The evaluation board sold by Parallax has the PWM period fixed at 10 ms — giving great accuracy, but a slow response. For convenience, I give construction details (Figure 1 A, B) for both kinds of accelerometer, but the ADXL202 is better.

Construction

Most of the lift on the Frisbee comes from its top, so it was safe to mount the circuit on the underside of the disc where it doesn't greatly affect the airflow. I put clear plastic tape over much of the circuit after assembly to smooth the airflow and minimize any drag effects.

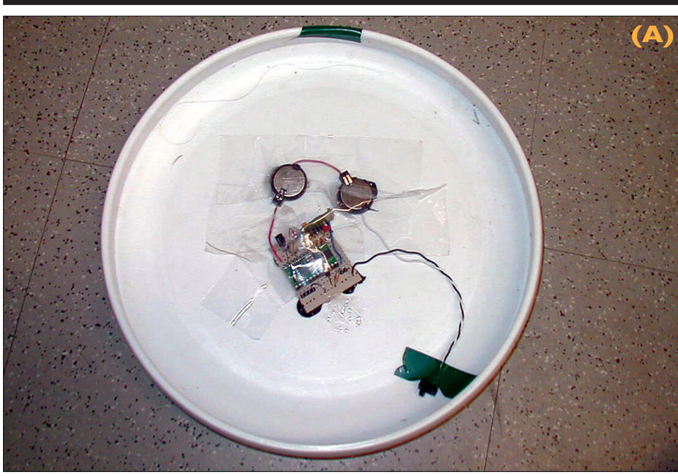
I assembled my first circuit on a piece of stripboard for sturdiness, but, since there are actually very few connections, it is easier (and lighter) to make individual wire connections to an IC socket. Complete with batteries and switch, the circuit board version weighed around 28 g; the bare-bones version was under 20 g (Figure 2). These weights are minimal when compared with the 175 g weight of the Frisbee — less than 20%.

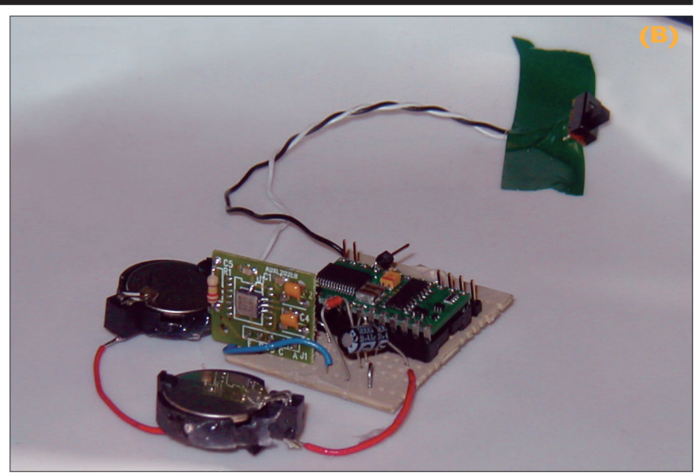
I added an LED, just to be able to see what the program was doing. The program strobes it rapidly when it is taking data, and goes on constantly afterwards when the code is reading out the data. A dark LED is a sure sign that something isn't working.

The other items in the circuit are the two cells connected in series (I gave them a few inches of wire, so that the cells could be placed around the center of the Frisbee, balancing it) and a slide switch. Placing this near the rim of the disc meant the circuit could be turned on just as I threw the Frisbee. I mounted all the items on the underside of the disc with silicone adhesive (Figure 3). It is important to mount the accelerometer as close to the center as possible. One accelerometer axis should be along the spin axis of the Frisbee.

One approach, if you have a BASIC Stamp breadboard, is to download the program to it, and transfer the chip to the Frisbee set-up. However, if you want to tweak the program, this can be tedious and tends to bend pins on the Stamp. What I did was to make a separate cable to link a nine-pin serial connector to pins 1-4 on the Stamp via a small header (Figure 4.) Because the serial handling for downloading the data from the unit after flight is easier, the data output is on pin 5 (P0) — a two-wire header (or two pins of a five-pin) connects pin 4 (ground) and pin 5 to a serial conector. This connector is easily attached after the flight.

Figure 2. Arrangement of parts on the underside of the Frisbee (A) with a close-up of the ADXL202 version, built on a small circuit board (B). The two circles are the lithium button cells. Green chip is the BASIC Stamp, small green board is the ADXL202EB.





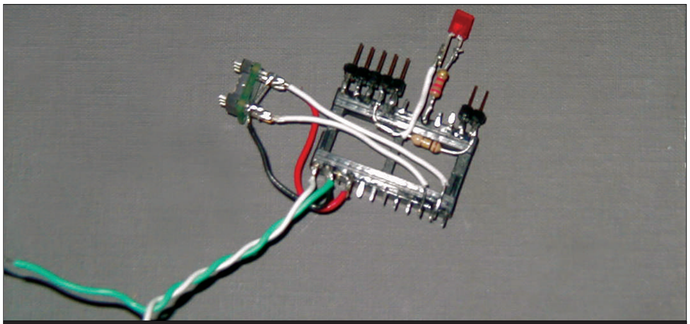


Figure 3. Close-up of "skeleton" boardless construction around the 24-pin IC socket, with the MEMSIC accelerometer on the left. Note the header pins for the realtime/sample-and-readout switch and serial connector.

The Program Operation

The BS2 has a 2 K EEPROM, which must contain the program, as well as any data. The program itself is quite short and leaves about 1,600 bytes of EEPROM memory spacefor data storage. The BS2 reads the accelerometer with the PulseIn command, which returns the length of a positive PulseIn the PWM output stream, measured in units ("ticks") of two microseconds. (I found that using two PulseIn commands reduces noise for the ADXL202, although for the MEMSIC, this slows the execution speed too much.)

Now, numbers like the PulseIn output are 16-bit (two byte) words. To store each reading for each of the two accelerometer axes would not only require two EEPROM write operations (which are slower than most of the BS2 operations, like arithmetic) and would require two of the precious bytes of EEPROM. But, adequate precision (about 2%) for this application can be had with only eight bits of data. The ADXL202 output is easily scaled to an eight-bit range (0-255) by subtracting about 80 from the output. The much slower MEMSIC device has a longer pulse length, and so the output, in ticks, needs to be divided by a factor of 10, as well as subtracted — you might need to fine-tune these numbers yourself. The program reads the sensors, performs this conversion, and stores one byte per reading in EEPROM.

Once the program has finished sampling (about 12 seconds for the ADXL202 version — long enough for anything except a record-breaking Frisbee flight!), it reads out the data to the serial port as two columns of numbers separated by a comma. The two accelerations are reported as eight-bit integers. To convert to real accelerations, I read the data into a spreadsheet program and convert according to a formula such as:

$$\text{Acceleration(g)} = \frac{\text{Reading - Reading(0g)}}{\text{Reading(1g)-Reading(0g)}}$$

where the 1 g reading is for that axis of the accelerometer pointed downwards, and the 0 g reading for the orthogonal axes.

For testing/debugging and getting these calibration readings, I found it easier to have the BS2 read data out in real time to the serial port, rather than storing and reading it out later. Rather than reprogramming the BS2 each time, I switched between the two modes with a jumper cable that acts as a switch on pin 12 — you could easily install a switch, although this might be heavier than a jumper. To simplify the wiring, I took the lazy approach of supplying the 5 V for this test from pin 11; pin 12 is pulled low by a 100 K resistor to ground, unless pins 11 and 12 are linked.

The data can be captured by setting up a terminal program (Hyperterminal is installed on most Windows PCs) — the settings have to be 9600 baud, 8 data bits, 1 stop bit, no parity, and no flow control. The data can be captured to a text file, converted as above in a spreadsheet program, and then graphed for analysis.

Making Sense of it All

The 800 readings in 12 seconds correspond to about 65 two-axis samples per second. (Using the MEMSIC device gets only about 30 samples per second, although the record lasts longer). You can get the sample rate by watching the LED to determine the exact time of the record and dividing by 800.

The record shows a violent disturbance as the disc is thrown. The axial accelerometer channel shows an almost constant time-average value of about -0.8 g, indicating almost level flight up to the end, although there are a lot of oscillations added from the wobbling of the slight-

PARTS LIST & VENDOR INFORMATION

24-pin IC socket
BASIC Stamp 2 (Parallax BS2-IC or Jameco #130892CF)
330 Ohm 1/4W resistor
Red LED
100K 1/4W resistor
slide switch
2x 2 pin header and connector

2x CR2032 lithium button cell (Jameco #14162CF)
2x button cell holder (Jameco #38535)

9-pin female D-type socket

MEMSIC 2125 (Parallax #28017) or
Analog ADXL202EB accelerometer (Jameco #177287)

(optional, for programming Stamp in-situ)
Replace one of 2-pin headers above with 5-pin header
and add one 4-pin connector and one 9-pin female D-type

www.jameco.com
www.parallax.com

See also

www.analog.com
www.memsic.com

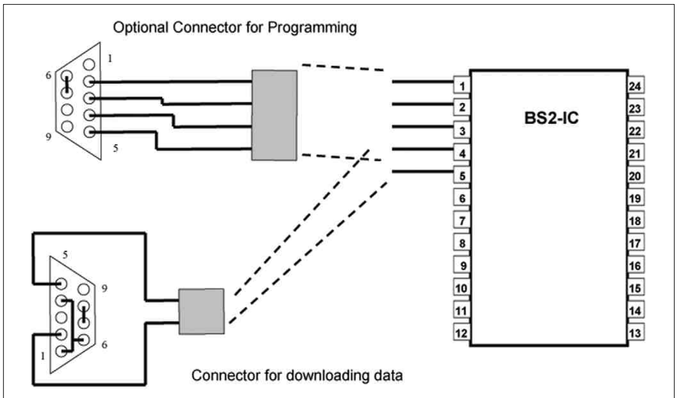


Figure 4. Serial connection details.

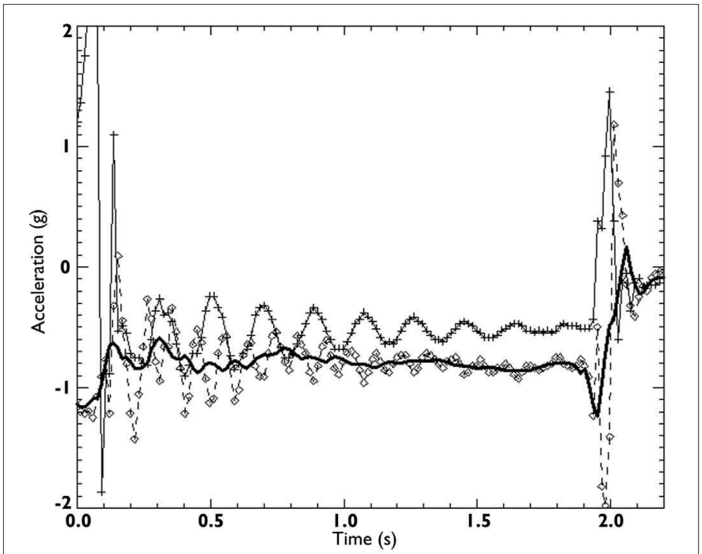


Figure 5. Flight results (see text). Diamonds show the wobble-modulated axial (lift) accelerometer, with a solid line showing smoothed data. Crosses are the spin-modulated radial (drag) accelerometer. Accelerations go out-of-range for the throw at the beginning and the impact at the end.

ly imbalanced Frisbee just after the throw. The radial accelerometer also shows a -0.5 g offset, due to the fact that the accelerometer isn't quite dead-center, and so it records a constant offset due to the centripetal acceleration, proportional to the square of the spin rate. The radial signal has a spin-modulated component about this mean, due to the accelerometer axis alternately being along and against the drag force (actually, the disc flies with a slight nose-up "angle of attack", so what is sensed here is drag force and a bit of lift that is inclined backwards). The period of this oscillation directly indicates the spin rate of the Frisbee, which a careful study shows to be decreasing from about 6.5 to about 5.5 revolutions per second.

Interpreting these results in quantitative aerodynamic terms is, of course, an involved business, but just looking at the graphs gives you a good idea of what is going on. Analyzing data like this might make a good science fair or other project.

Other Ideas

You could use this sort of circuit on a radio-controlled airplane, car, or boat. A similar circuit could be used for a model rocket, although the g-loads will be much larger than the ±2 g range of the ADXL202, so a different accelerometer would need to be used — the ADXL210 is similar to the 202, but with a 10 g range. For higher accelerations, you may need to use more sophisticated circuitry with an analog-to-digital converter, as PWM outputs are not typical for such high-g devices.

You could also try all kinds of variants on a circuit like this — photodiodes to measure the position of the sun and hence the "wobble" on the Frisbee or pressure sensors to measure the suction that causes the Frisbee's lift. Maybe infrared or ultrasonic rangers could tell you the altitude as a function of time. Happy flying! **NV**

ABOUT THE AUTHOR

*Dr. Ralph Lorenz is a planetary scientist at the University of Arizona, where his studies focus on Saturn's moon, Titan. He enjoys building small sensor systems and learning about the physical world with them. Visit his website at **www.lpl.arizona.edu/~rlorenz***

HUMAN ERROR and the Engineering Design Process

by R.B. Whittingham

The Health and Safety Executive has estimated that 80% of accidents are caused by human error in some form. Loss of production and profitability due to human error is probably incalculable, but is likely to run to many hundreds of millions of pounds per year. There is a common misconception that human error is unavoidable and usually arises from carelessness or neglect. From this, there follows a general belief that human error can only be prevented by identifying, blaming, and correcting the individual who made the error. In reality, nearly all instances of human error are the consequence of badly designed systems. The systems may be technological, such as the design of the human machine interface (e.g., an aircraft cockpit display) or the work environment (e.g., how an item of industrial machinery is operated). Alternatively, the systems may be organizational, varying from an operating or maintenance procedure to a management system, or indeed, the culture of a whole company.

In all cases, the systems which influence the way work is carried out are the main cause of human error. If a system is badly designed from a human operability perspective, then the probability of errors occurring will be increased. Errors caused by system deficiencies are known as systemic errors and it follows from this that, by careful attention to design, their incidence can be limited. Once it is accepted that most errors are caused by defective systems rather than neglect, then human error is no longer seen as inevitable. Indeed, if the system faults can be identified and corrected, then there is a possibility for error reduction and blame can be virtually eliminated from the equation. However, it also means that the remedy for human error often lies in the hands of the mechanical and electrical engineers who designed the system in the first place.

There are two basic approaches to the design of equipment from an operability point of view. The system-centered approach has tended to be the traditional method adopted in the design process. Here, the attention of the design engineer is almost totally directed towards the system to the exclusion of the human beings who will have to operate or maintain it. Today, many designers are still tempted to adopt this old-fashioned approach. Their natural inclination is to focus upon the system rather than the human being because of the perception that it is the system that delivers the specified requirements. However, it needs to be seen that the system comprises both human and machine. The end result of such an approach is that the operator or maintainer must adapt to a system that is not designed to take account of their needs. Quite often the discovery that the human being cannot easily adapt to the system is not realized until the product is brought into operation. By this time, it is often too late or very expensive to make the required changes.

It is sometimes argued that designers do not have the required knowledge of ergonomics (see resources) to be able to take into account human factors in their designs. However, in many cases, all that is required is an ability to understand how the system will eventually be operated or maintained. This may involve no more than the application of simple common sense. The result of designing equipment without the application of such

RESOURCES

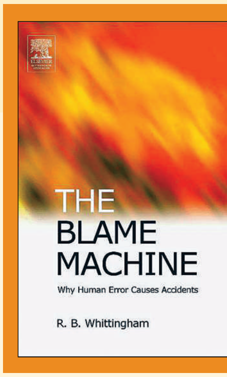
1. Ergonomics is "an approach which puts human needs and capabilities at the focus of designing technological systems. The aim is to ensure that humans and technology work in complete harmony, with the equipment and tasks aligned to human characteristics." The Ergonomics Society, 2003, **www.ergonomics.org.uk/ergonomics/definition.htm**

2. *The Blame Machine — Why Human Error Causes Accidents*, Elsevier Science and Technology Books, Oxford, R.B. Whittingham, 2003, ISBN 0750655100

thinking is that when it is brought into operation, even the most highly trained and well-motivated personnel will make systemic errors leading to accidents or loss of production.

By contrast, the user-centered approach ensures that the design of the system is matched as closely as possible to human capabilities and limitations. *The Blame Machine — Why Human Error Causes Accidents* (see Resources) provides numerous case studies of accidents caused by designs that ignored human capabilities. The most serious aircraft accident to occur in the UK for many decades occurred at Kegworth near Nottingham in 1987. The accident resulted from an engine instrument layout that presented important information in a misleading way. The system may have appeared adequate until the pilots were faced with an emergency where rapid decisions were called for based on engine data from the instrument panel. Under conditions of high workload and stress, the mental resources of the pilots were overstretched. This restricted their capacity to properly assimilate information from a vibration monitor resulting in the shutting down of the wrong engine. Because the presentation of that information was poor, the probability of an error was increased and was the main cause of the accident at Kegworth.

Unfortunately, the need to adopt a user-centered approach is still — even today — not fully understood by many designers. As a result, there are numerous examples of complex technological systems designed mainly with system functionality in mind, ignoring the capabilities and limitations of the user. Such systems invariably result in degraded levels of human performance with grave consequences for productivity, equipment availability, and safety. However, the need of the engineering designer — who is not necessarily an expert in human factors — should also be recognized. A basic appreciation of techniques such as Task Analysis, Human Error Analysis, and an understanding of the various Error Types, Forms, and Taxonomies will help designers to recognize how common human errors occur. This understanding will lead to safer and more cost effective designs of equipment which take full account of potential human



ABOUT THE AUTHOR

R.B.Whittingham is an author, risk consultant, and chemical engineer with 40 years experience in plant and technical management, design engineering, and safety consultancy in the chemical, oil and gas, railway, aviation, and nuclear industries. He has a special interest in the role of human error in accident causation and the use of human error analysis to predict the likelihood and causes of potentially dangerous errors.

What is VIRTUAL MEMORY?

by Mark Balch

Virtual memory is a technology embedded in most personal computers that enables many of the advanced operations that we are so accustomed to. However, the term is only vaguely familiar to many people. When you paste text from your web browser into your word processor, multiple applications are running simultaneously with the operating system (OS) to make it all happen. Virtual memory plays a key role in allowing those applications to coexist with each other and with the OS.

Multitasking

Multitasking operating systems execute multiple programs at the same time by assigning each program a certain percentage of the microprocessor's time and then periodically changing which instruction sequence is being executed. This is accomplished by a periodic timer interrupt that causes the OS kernel to save the state of the microprocessor's registers and then reload the registers with a preserved state from a different program. Each program runs for a while, is paused, and then execution resumes without the program having any knowledge of being paused. In this respect, the individual programs in a multitasking environment appear to have complete control over the computer, despite sharing the resources with others.

Aside from fair access to microprocessor time, conflicts can arise between applications accidentally modifying portions of each other's memory — either program or data. How does an application know where to locate its data so that it will not disturb that of other applications and so that it will not be overwritten? There is also the concern about system-wide fault tolerance. Even if not malicious, programs may have bugs that cause them to crash and write data to random memory locations. In such an instance, one errant application could bring down others or even crash the OS if it overwrites program and data regions that belong to the OS kernel.

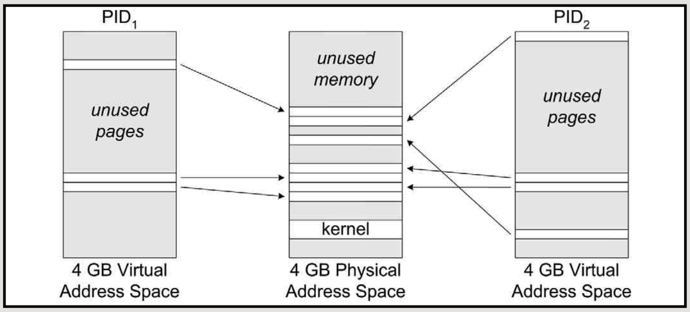


FIGURE 1. 32-bit Virtual Memory Mapping

Virtual Memory

Virtual memory is a hardware enforced and software configured mechanism that provides each application with its own private memory space that it can use arbitrarily. This virtual memory space can be as large as the microprocessor's addressing capability — a full 4 GB in the case of a 32-bit microprocessor. Because each application has its own exclusive virtual memory space, it can use any portion of that space that is not otherwise restricted by the kernel. Virtual memory frees the programmer from having to worry about where other applications may locate their instructions or data because applications cannot access the virtual memory spaces of others.

The MMU

Clearly, multiple programs cannot place different data at the same address or each simultaneously occupy the microprocessor's entire address space. The OS kernel configures a hardware memory management unit (MMU) to map each program's virtual addresses into unique physical addresses that correspond to actual main memory. Each unique virtual memory space is broken into many small pages that are often in the range of 2 KB to 16 KB in size (4 KB is a common page size). The OS and MMU refer to each virtual memory space with a process ID (PID) field. Virtual memory is handled on a process basis rather than an application basis because it is possible for an application to consist of multiple semi-independent

processes. The high-order address bits referenced by each instruction form the virtual page number (VPN). The PID and VPN are combined to uniquely map to a physical address set aside by the kernel as shown in Figure 1.

Low-order address bits represent offsets that directly index into mapped pages in physical memory. The mapping of virtual memory pages into physical memory is assigned arbitrarily by the OS kernel. The kernel runs in real memory rather than in virtual memory so that it can have direct access to the computer's physical resources to allocate memory as individual processes are executed and then terminated.

Despite each process having a 4 GB address space, virtual memory can work on computers with just megabytes of memory because the huge virtual address spaces are sparsely populated. Most processes use only a few hundred kilobytes to a few megabytes of memory and, therefore, multiple processes that collectively have the potential to reference tens of gigabytes can be mapped into a much smaller quantity of real memory.

If too many processes are running simultaneously, or if these processes start to consume too much memory, a computer can exhaust its physical memory resources, thereby requiring some intervention from the kernel to either suspend a process or handle the problem in some other way.

Memory Allocation

When a process is initiated, or spawned, it is assigned a PID and given its own virtual memory space. Some initial pages are allocated to hold its instructions and whatever data memory the process needs available when it begins. During execution, processes may request more memory from the kernel by calling predefined kernel memory management routines. The kernel will respond by allocating a page in physical memory and then returning a pointer to that page's virtual mapping. Likewise, a process can free a memory region when it no longer needs it. Under this circumstance, the kernel will remove the mapping for the particular pages, enabling them to be reallocated to another process — or the same process — at a later time. Therefore, the state of memory in a typical multitasking OS is quite dynamic and the routines to manage memory must be implemented in software due to their complexity and variability according to the platform and the nature of processes running at any given time.

Swapped!

All mapped virtual memory pages do not have to be held in physical RAM at the same time. Instead, the total virtual memory allocation on a computer can spill over into a secondary storage medium such as a hard drive. The hard drive will be much slower than DRAM, but not every memory page in every process is used at the same time. When a process is first loaded, its entire instruction image is typically loaded into virtual memory. However, it will take some time for all of those instructions to reach their turn in the execution sequence. During this wait time, the majority of a process's program memory can be stored on the hard drive without incurring a performance penalty. When those instructions are ready to be executed, the OS kernel will have to transfer the data into physical memory. This slows the system down, but makes it more flexible without requiring huge quantities of DRAM.

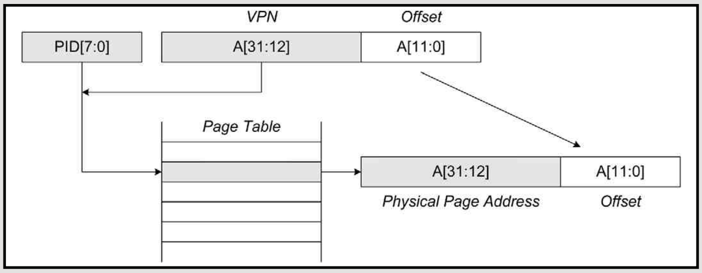
Part of the kernel's memory management function is to decide which virtual pages should be held in DRAM and which should be swapped out to the disk. Pages that have not been used for a while can be swapped out to make room for new pages that are currently needed. If a process subsequently accesses a page that has been moved to the disk, that page can be swapped back into DRAM to replace another page that is not needed at the time. A computer with 256 MB of DRAM could, for example, have a 512 MB swap file on its hard drive, enabling processes to share a combined 768 MB of used virtual memory.

This scheme of expanding virtual memory onto a disk effectively turns the computer's DRAM into a large cache for an even larger disk-based memory. A virtual memory page that is not present in DRAM is effectively a cache miss with a large penalty because hard disks are much slower than DRAM. Such misses are called page faults. The MMU detects that the requested virtual memory address from a particular PID is not present in DRAM and causes an exception that must be handled by the OS kernel. It is the kernel's responsibility to swap pages to and from the disk. For a virtual memory system to function with reasonable performance, the working set of memory across all the processes running should be able to fit into the computer's physical memory. The working set includes any instructions and data that are accessed within a local time interval. Processes with good locality characteristics will do well in a virtual memory system. Processes with poor locality may result in thrashing as many sequential page faults are caused by random accesses throughout a large virtual memory space.

Page Tables

The virtual to physical address mapping process is guided by the kernel using a page table, which can take various forms, but must somehow map each PID/VPN combination to either a physical memory page or one located on the disk drive's swap area. Virtual page mapping is illustrated in Figure 2, assuming 4 KB pages, a 32-bit address space, and an 8-bit PID. In addition to basic mapping infor-

FIGURE 2. Virtual Page Mapping



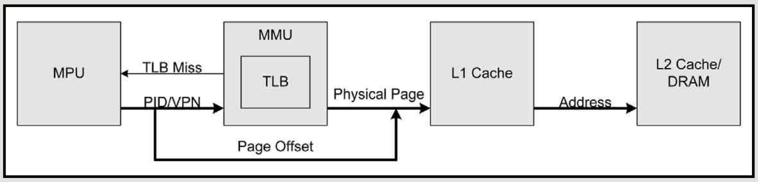


FIGURE 3. Location of TLB

mation, the page table also contains status information including a dirty bit that indicates when a page held in memory has been modified. If modified, the page must be saved to the disk before being flushed to make room for a new virtual page. Otherwise, the page can be flushed without further action. Given a 4 KB page size and a 32-bit address space, each process has access to 2^{20} = 1,048,576 pages. With 256 PIDs, a brute-force page table would contain more than 268 million entries! There are a variety of schemes to reduce page table size, but there is no escaping the fact that a page table will be large. Page table management schemes are largely an issue of OS architecture and are outside the scope of this discussion. The fact that the page table is large and is parsed by software means that the mapping process will be extremely slow without hardware assistance. Every access to virtual memory, in other words almost every access performed on the computer, requires mapping, which makes hardware acceleration critical to the viability of virtual memory.

Translation Lookaside Buffer

Within the MMU is a translation lookaside buffer (TLB), a small, fully associative cache that allows the MMU to rapidly locate recently accessed virtual page mappings. Typical sizes for a TLB are just 16 to 64 entries because of the complexity of implementing a fast fully associative cache. When a process is first spawned, it has not yet performed virtual memory accesses, so its first access will result in a TLB miss. When a TLB miss occurs, an exception is generated that invokes the kernel's memory management routine to parse the page table in search of the correct physical address mapping. The kernel routine loads a TLB entry with the mapping information and exits. On subsequent memory accesses, the TLB will hit some and miss some. It is hoped that the ratio of hits to misses will decline rapidly as the process executes.

As more processes actively vie for resources in a multi-tasking system, they may begin to fight each other for scarce TLB entries. The resources and architecture of a computer must be properly matched to its intended application. A typical desktop or embedded computer may get along fine with a small TLB because it may not have many demanding processes running concurrently. A more powerful computer designed to simultaneously run many memory intensive processes may require a larger TLB to take full advantage of its microprocessor and memory resources. The ever-present trade-off between performance and cost does not go away!

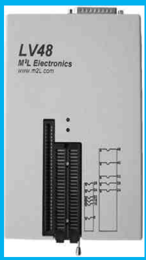
The TLB is usually located between the microprocessor and its cache subsystem, as shown in Figure 3, such that physical addresses are cached rather than virtual addresses. Such an arrangement adds latency to microprocessor transactions because the virtual-to-physical mapping must take place before the L1 cache can respond. However, a TLB can be made very fast because of its small size, thereby limiting its time penalty on transactions.

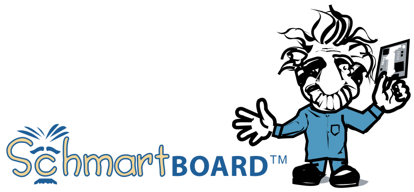
Virtual Memory for the Masses

Years ago, virtual memory was found only on large, expensive computers. As more gates were squeezed into integrated circuits, the MMU became an economical complement to the microprocessor. Modern operating systems, and the applications that run on them, gain substantial functional and performance enhancements, from this technology that was once reserved for mainframe computing. **NV**

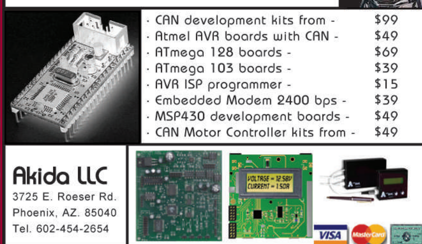
About the Author

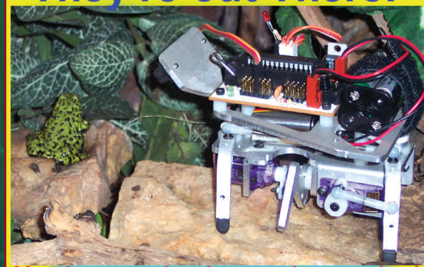
Mark Balch is the author of *Complete Digital Design*. He is an electrical engineer in Silicon Valley, CA, who designs high-performance computer-networking hardware. His responsibilities have included PCB, FPGA, and ASIC design. Mark has designed products in the fields of HDTV, consumer electronics, and industrial computers. Mark holds a bachelor's degree in electrical engineering from The Cooper Union in New York City. He can be reached via email at mark_balch@hotmail.com.

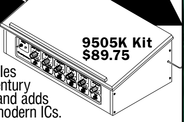


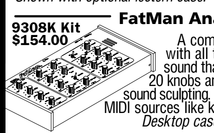


Electronics Showcase







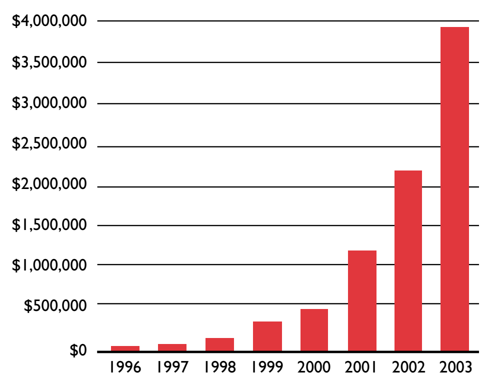


News Bytes

Colleges Want for FIRST Students

Most high school students think that participating in the annual FIRST robotics competition is merely a good way to meet friends, build cool robots, learn some new skills — and maybe even win a regional competition. However, due to the high technical capabilities of emergent FIRST graduates over the past five years, adding this item to your college application could really boost your chances of rising above the competition. Note that, in 2003, 36 universities offered nearly $3.8 million in scholarships to the 25,000 high school participants of FIRST. (In addition, over 700 corporations provided sponsorship and career opportunities.) So, if you're a student and not on a FIRST robotics team at your school, think twice about getting that job flipping burgers — think about what applying your mind might do for your future education. If you're an engineer with a dozen hours to spare, consider contacting the sponsor at your local high school to volunteer as a mentor. Even a small amount of knowledge can impart a huge amount of inspiration to a young engineer — with the potential to change his/her life. More information is available on their website, **www.usfirst.org**

FIRST Scholarship Oportunities 1996-2003



▲ FIRST scholarship funds

New Hybrid Undersea ROV Is Commissioned

The Woods Hole Oceanographic Institution recently received $5 million in funding to design and construct

a self-powered undersea robot capable of descending 11,000 meters — deeper than any existing research vehicle. The new robot is described as a hybrid because it will be able to operate either connected to a fiber optic umbilical or in a free-swimming mode. The navigation and control systems will employ technology developed by members of the Whiting School of Engineering's Department of Mechanical Engineering at Johns Hopkins University.

"The HROV will enable, for the first time, routine scientific research in the deepest parts of the ocean, from 6,500 meters to 11,000 meters — a depth we currently cannot reach," says Richard Pittenger, WHOI Vice-President for Marine Operations. "It will also afford access to other very hard to reach regions, such as under the Arctic ice cap. The HROV's real-time, wide-band link to the surface will put the researcher in the loop to view, assess and command the vehicle throughout the duration of dive missions. It is the first capable and cost-effective technology that will enable scientists to pursue research projects on a routine basis in areas they have long wanted to study, but have been unable to reach. HROV technology will help answer many questions about the deep sea."

More information is available on their website, **www.whoi.edu/media/hrov.html**

Near Space

How Some Hobbyists are Getting Around the Difficulties Associated with Amateur Space Exploration

Part 1

by L. Paul Verhage

Many of us dream of exploring space. Two outlets for this dream are amateur astronomy and rocketry. Neither of these hobbies, though, can match the sheer awe of building and launching a private spacecraft. Unfortunately, there are major roadblocks to this dream of amateur space exploration.

No doubt, you can list the many obstacles that stop us from constructing a spacecraft; my list goes like this. We cannot build our own spacecraft because of the high cost of space-rated materials, the difficulty of machining spacecraft parts, and the amount of time involved in construction. In addition, our lack of access to a clean room and our inability to properly test a spacecraft at various stages of its construction will stop us, even if we do have the necessary parts, skills, and free time.

If we manage to build a spacecraft, I can think of two additional obstacles stopping us from launching it. These after-construction obstacles are the length of time we must wait for the launch and the cost of the launch itself. How can we justify the time and money needed to assemble a spacecraft when we know that we will wait a year for launch and that we can hardly afford the launch in the first place?

Even if we construct and launch our spacecraft, there's one final obstacle: telemetry. As amateurs, we have no access to professional telemetry stations, nor can we afford to build a series of public telemetry stations around the world. If we can't collect data from our spacecraft, then we simply will not build it. Until the hobbyist can create, launch, and record data from his or her own spacecraft, there will be no such thing as amateur space exploration.

Recently though, hobbyists have found a creative solution to the dream. They substitute weather balloons and helium for costly rocket boosters. They use off-the-shelf components to assemble a functioning model of a spacecraft, and they use amateur radio for spacecraft telemetry. These few hobbyists are constructing what are called near spacecraft and launching them deep into the stratosphere, or near space. A near space program is often called the poor man's space program and it makes an amateur science hobby that is nearly out of this world.

This article explores the amateur's version of a near space program and how it solves the many obstacles mentioned above. Read this article and you'll learn how similar near space is to outer space. Then, you'll see how easy it is for the hobbyist to build his or her own near spacecraft and launch vehicle. Finally, you'll become familiar with some of the benefits of starting your own amateur near space program.

My article is too short to teach you everything you need to know; however, I hope it will convince you that an amateur near space program is a hobby that you can, and should, take up. From there, you can get the help you need from the resources listed at the end of this article.

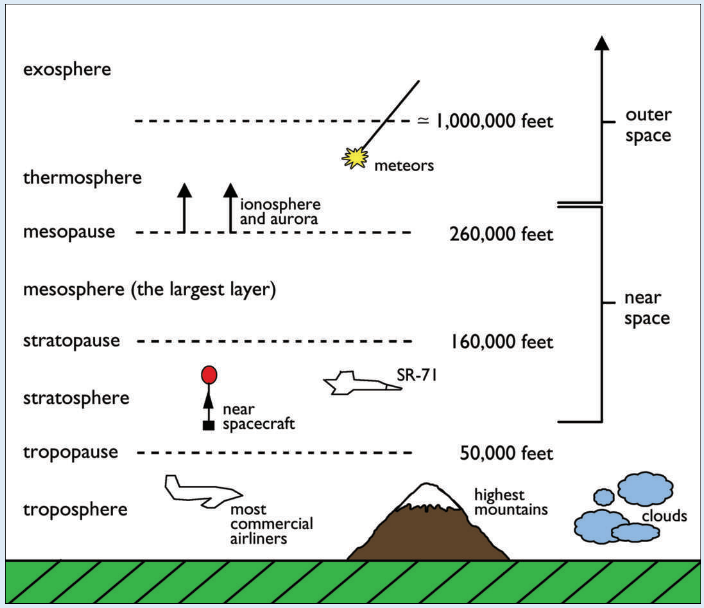
The Earth's Atmosphere

Before learning about near space, you must first become familiar with the structure of our atmosphere.

There are five layers in our atmosphere, each with its own name and set of characteristics. We live and play in the troposphere, the lowest layer of our atmosphere. Our weather occurs in this layer and most aircraft fly in it. The troposphere extends to an altitude of around 50,000 feet at a boundary called the tropopause. The exact altitude of the tropopause depends on the time of the year and latitude.

The next highest layer is called the stratosphere. Residing in the stratosphere is the ozone layer that protects us from the sun's harmful ultraviolet radiation. Very few aircraft can fly in this layer. For the most part, we are very unaware of the stratosphere. The stratosphere extends to an altitude of around 160,000 feet at a boundary called the stratopause.

Above the stratopause is a layer of the atmosphere called the mesosphere. Only rockets and meteors travel through this layer. Above the mesosphere is the thermosphere and then the exosphere. There is a boundary between the thermosphere and exosphere (called, you guessed it, the thermopause), but no top boundary to the exosphere. Outer space exists in the two topmost layers of our atmosphere.



Layers of the Earth's atmosphere.

Environmental Conditions in Near Space

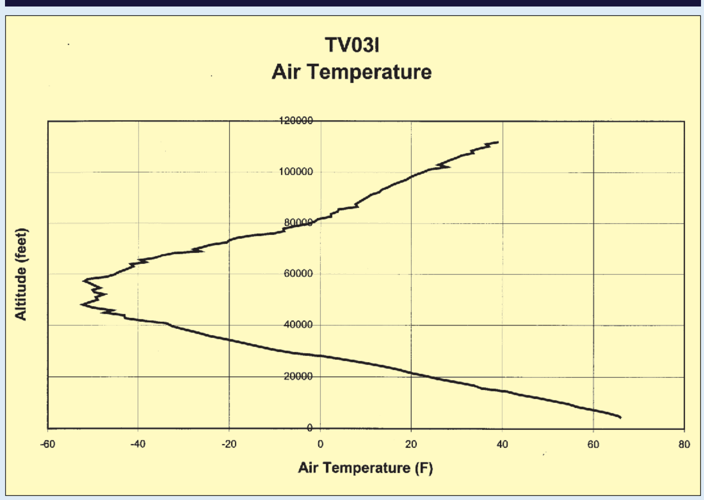
Now that you're familiar with the structure of our atmosphere, we can put near space into perspective by discussing its location and environmental conditions. First, where is near space located? I define near space as those altitudes in the stratosphere and mesosphere between 75,000 feet and 330,000 feet. I selected the lower boundary because of the environmental conditions found at this altitude and the higher boundary because it is the internationally defined boundary for outer space. For an altitude comparison, many of you have flown in commercial aircraft, which fly at an altitude between 30,000 and 40,000 feet.

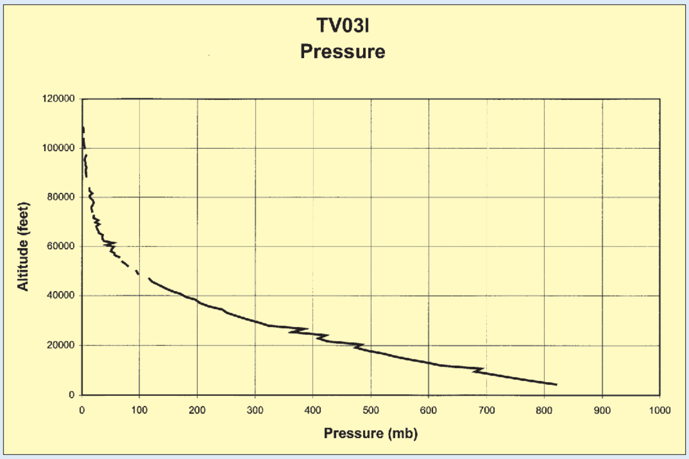
Now, what's it like in near space? There are a number of unique conditions found in near space. The first is its temperature. Let's launch a near spacecraft and see what it tells us about temperature (please see the charts accompanying this article). As our near spacecraft ascends in the troposphere, we find that the air temperature continuously decreases. The troposphere cools with altitude because it's warmed by its contact with the ground. You might think that the troposphere should be warmed by sunlight, but, the troposphere is very transparent to sunlight, so sunlight shines right through it without warming it. Once our near spacecraft passes through the tropopause, sensors find that the air temperature stops cooling. During the summer, the tropopause occurs at an altitude of 50,000 feet for mid-latitudes and the air temperature is a chilly -60° Fahrenheit. In the winter, the tropopause lowers to an altitude of 40,000 feet and its temperature can drop to an even colder -90° Fahrenheit.

Once our near spacecraft enters the stratosphere, we find that the air temperature increases with altitude. At an altitude of 100,000 feet — which is easily reached by our near spacecraft — the air temperature can warm to 20° Fahrenheit or warmer. The stratosphere warms with increasing altitude because of its ozone content. The sun's ultraviolet radiation is blocked by our ozone layer. Recall that energy cannot be created or destroyed; it may be in another place and possibly in a new form. In the stratosphere, energy from the sun's ultraviolet radiation is eventually converted into higher air temperatures. As our near spacecraft gets closer to the sun, there is more ultraviolet radiation for the ozone to block, and, therefore, warmer air temperatures.

The second condition found in near space is reduced air pressure. As opposed to the up and down changes in air temperature that our near spacecraft detected, air pressure can only decrease with increasing altitude. Our near spacecraft sees air pressure dropping by a factor of two for

Air temperature cycles as altitude increases.

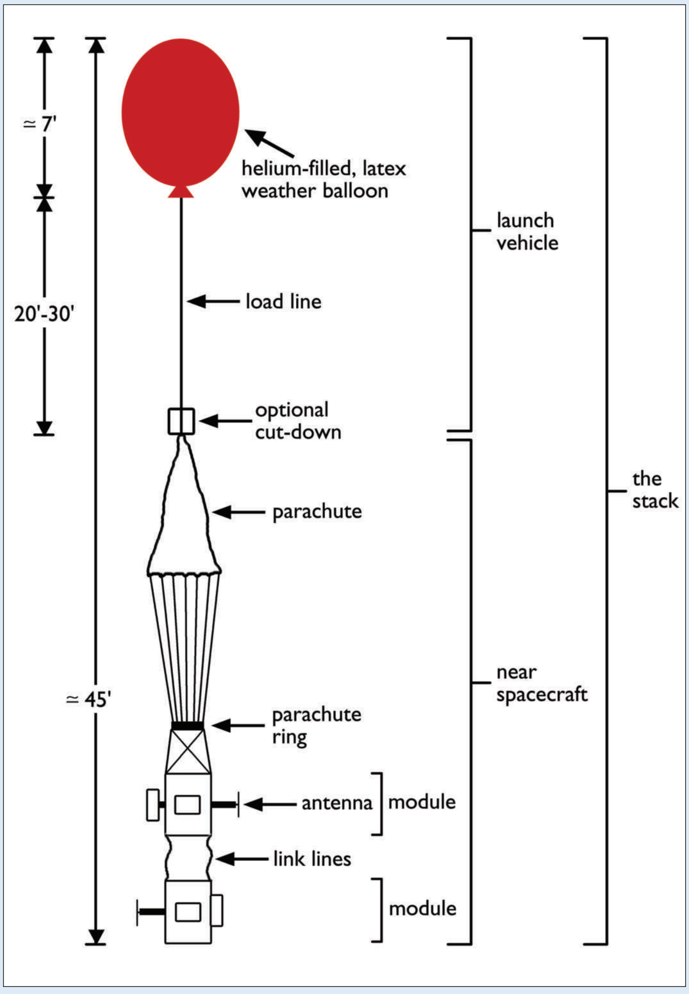




Not surprisingly, atmospheric pressure decreases with altitude.

every 18,000 foot change in altitude. At 75,000 feet, our near spacecraft measures an air pressure less than 6% of the air pressure found at sea level, or about 95% vacuum. At 100,000 feet, our near spacecraft measures an air pressure only 1% of the air pressure at sea level. It is 99% vacuum at 100,000 feet! As a result of these low air pressures, the sky becomes inky black in color. The reduction in air pressure (or more specifically, air density) has one more effect and that deals with cosmic rays. In near space, with fewer air molecules to create a shield, the cosmic ray flux is over 100 times greater than at sea level.

The "Stack" — Component parts of the integrated launch vehicle and near spacecraft.



The third condition found in near space is what happens to the earth's horizon. There are three amazing effects.

First, the distance to the horizon increases. Remember that a six foot tall adult sees a horizon that is typically three miles away. At an altitude of 75,000 feet, our near spacecraft sees a horizon that is 335 miles away. At 100,000 feet, the horizon is closer to 400 miles away. So at 100,000 feet, our near spacecraft can see our entire state in a single glance.

Another effect of altitude on the earth's horizon is that it makes the earth's curvature noticeable. Photographs taken of the earth's horizon from near space show the edge of the earth to be curved and this should be enough to satisfy the members of the Flat Earth Society (not!).

The final effect that altitude has on the earth's horizon is that the horizon gets lower. This effect is sometimes called depression of the horizon. The effect is very noticeable to astronauts on the Space Shuttle where they orbit earth at an altitude of 300 nautical miles. You don't have to orbit the earth, though, to see this effect. Even our near spacecraft can detect this effect. At an altitude of 100,000 feet, our near spacecraft sees a horizon that is more than five degrees lower than it is at sea level. So the angular distance from horizon, to zenith, to opposite horizon spans more than 190°.

The final condition found in near space that I will discuss is gravity. The higher our near spacecraft climbs, the less gravitational force earth exerts.

Now, this is not the same effect noticed by astronauts. When in orbit about the earth, an astronaut is in a state of constant freefall. As a result, s/he feels weightless. This weightlessness overwhelms the reduction of gravity due to the distance that the Space Shuttle orbits from the earth's center.

However, in near space, we can detect a change in the earth's gravity. At an altitude of 100,000 feet, the acceleration due to gravity is 1% less. Consequently, our near spacecraft weighs only 99% of its weight at sea level.

You can see that the conditions in near space look and feel much like space. There is no means for the hobbyist to create these conditions on a large scale. If we want to experience space vicariously, then the amateur near space program is the only game in town.

Getting Into Near Space

Now that you're familiar with the location and conditions found in near space, let's talk about how we get there. There are two elements to getting into near space:

the launch vehicle that does the heavy lifting and the near spacecraft that does the thinking.

The Launch Vehicle

To get into near space, you need a launch vehicle. Amateurs most frequently use a launch vehicle consisting of a latex weather balloon, helium, and a length of nylon cord. Amateurs purchase their weather balloons from either Kaymont or Kaysam (see Resources). You should expect to pay about $50.00, plus shipping, for a 1,200-gram balloon. A balloon this large has enough volume to get a 12-pound near spacecraft to an altitude of 85,000 feet. If you use a larger balloon or lower the weight of your near spacecraft, you can reach even higher altitudes.

Purchase your helium from a welding shop and never from a department store. Department store helium is fine for filling party balloons, but your 1200-gram weather balloon requires over 300 cubic feet of helium. If you purchase helium from your local welding shop, they'll sell you a purer grade of helium and a lower cost per volume.

The load line of the launch vehicle is just a length of nylon cord. This is the same kind of nylon cord or twine sold in places like hardware stores. The cord is strong enough to lift the near spacecraft and able to separate from the balloon nozzle with a minimum of force. The load line is cut to a length of between 20 to 30 feet and all its knots are wrapped in small pieces of duct tape for extra security.

The Near Spacecraft

Your near spacecraft consists of a recovery parachute and one or more modules. If more than one module is used, you will connect them together with link lines. You may also use an umbilical to share power and data between the modules. On some occasions, you might place a cutdown on the load line between the near spacecraft and its launch vehicle. A cutdown is not required, but when it is used, it separates the near spacecraft from its launch vehicle. A cutdown is used to terminate missions early or to separate the balloon remains from the parachute during the descent phase of a mission.

The Recovery Parachute

The recovery parachute protects private property and your near spacecraft. You can either purchase your parachute from a rocketry company or sew it yourself (I prefer to sew my own). Depending on the porosity of the canopy's fabric, your 13-pound near spacecraft (12 pounds for the modules and one pound for the recovery parachute) will require a parachute about six feet in diameter.

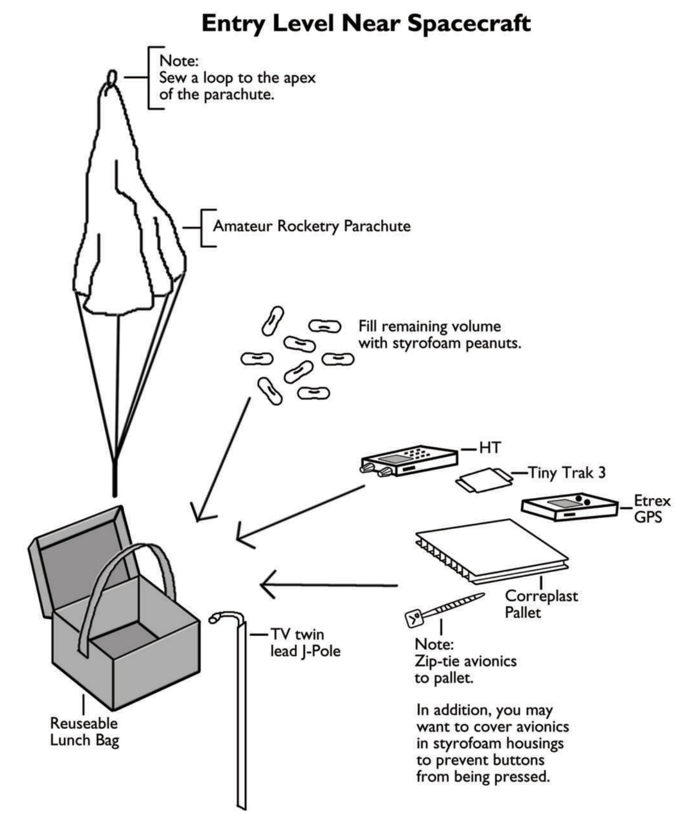
Never launch the recovery parachute folded; instead, the launch vehicle lifts the parachute by its apex in a pre-deployed position. This way, the parachute opens immediately upon balloon burst. Remember how long the load line was? It's this long to make sure that the burst balloon (which remains tied to the other end of the load line) can fall over the side of the parachute canopy, rather on top of the parachute canopy, possibly collapsing it.

Preparing for lift-off!

Modules

A module consists of an airframe, avionics, and possibly experiments. Some airframes are purchased ready to fly while others are specially constructed. The avionics are either a radio tracker or a flight computer. Some avionics are mounted to a pallet that fits inside the airframe, while others are packed in foam rubber. A pallet is a lightweight means to keep elements of the avionics from bouncing

More spacecraft than the Baikonur Cosmodrome.



Components of the near spacecraft.

around during a mission, just like foam rubber does. When possible, use a standardized airframe design and avionics pallet. This way, you can have several airframes and avionics pallets that can be mixed and matched as needed.

Experiments are the element that changes the most. Typically, each new mission switches out the old experiments for new ones. These experiments are what excite me the most about the amateur near space program.

Airframes

The fastest way to get an airframe is to purchase an insulated and reusable lunch bag. In this style of airframe, the avionics are either mounted to a sheet of correplast (a pallet) with zip ties or fitted into a block of foam rubber that has been cut to fit the interior space of the lunch bag. Never rely on the rubber ducky antenna that comes with most handheld radios, as they tend to have poor gain. Instead, use a flexible J-Pole or dipole antenna connected to the handheld radio's antenna jack. The rest of the antenna is left dangling outside of the closed bag. Parachute shroud lines are attached securely to the hand strap. Never use a snap swivel to attach the parachute to the airframe, as it can pop open. A popped snap swivel terminates a near space mission much sooner than planned. A reusable lunch bag and simple tracker, as described below, make an ideal first near spacecraft or backup tracker for a more advanced near spacecraft design.

More elaborate airframes are constructed from a 3/4" thick Styrofoam sheet. The best source of this material is the blue or pink Styrofoam sheeting used to insulate homes. This material is very popular and can be found at virtually every home improvement store. Styrofoam is the ideal material because it is strong, warm, lightweight, and inexpensive. Styrofoam is also very easy to machine; you only need a sharp Xacto knife and metal straight edge to cut the foam. A good adhesive to glue the sides of your cut Styrofoam panels together is hot glue. As it sets very quickly, hot glue is as easy to work with as Styrofoam. Just be sure to keep the glue below its maximum temperature, because it can begin to melt the Styrofoam.

After constructing your airframe, you may wish to add more insulation to its exterior. To keep spacecraft warm, aerospace companies wrap their spacecraft in multilayer insulation (MLI). Their MLI is constructed from alternating layers of space-rated aluminized Mylar or Kapton and a scrim (plastic mesh) inner layer. A homemade version of MLI is made from space blanket and wedding veil material. At this time, however, I'm not certain the vacuum of near space is "hard" enough to make the MLI effective.

During its mission, the interior of your near spacecraft module will chill in the freezing air. The cold of near space is severe to some items, like batteries. From personal experience, I can tell you that cold batteries can make for a bad day. In some cases the batteries get so cold that they fail

and shut down telemetry from your near spacecraft (ever see the movie, *Lost In Near Space*?).

There are two things you can do to prevent this. The first is to use lithium cells. The chemistry of lithium cells holds up to cold much better than most other battery chemistries. The second is to cover the exterior of the airframe in dark fabrics. A jacket of dark fabric absorbs solar radiation and will passively heat the interior of the module. Besides warming the module, a fabric jacket will also protect the MLI and airframe exterior from abrasion during landing. It's also a great place to attach link lines between modules. I use ripstop nylon for my fabric jackets, which I call abrasion jackets. You've most likely seen ripstop nylon used in fabric kite sails.

Avionics for Near Space

The electronics used to operate a near spacecraft are called avionics (aviation electronics). For your first near space mission, I recommend using a simple amateur radio tracker. A simple and inexpensive amateur radio tracker consists of a terminal node controller connected to a GPS receiver and a handheld, two-meter, amateur radio (see Resources).

The terminal node controller (TNC) is a modem built for radio use. When used in avionics, it accepts sentences from a GPS receiver and formats them for transmission over the radio.

Afterwards, it keys the radio and sends the proper tones. A similar set-up on the ground decodes the tones and displays the data on a laptop or PC. This method is referred to as the Automatic Packet Reporting System (APRS) and is very popular with the amateur radio community.

Because of APRS, the position of the near spacecraft in three dimensions, its speed, and its heading are known to chase and recovery crews.

The simple tracker costs around $250.00, but don't let the cost scare you. Assembling your tracker is a one-time expense, because it is used on every mission. Besides, the cost of a tracker is less than the cost of a good set of golf clubs. Not only does a tracker cost less, but the aggravation associated with it is less than the aggravation associated with the same set of golf clubs.

The next step up from a radio tracker is a flight computer. Most of the flight computers used by amateurs today are based on programmable microcontrollers like the PIC, Rabbit, or BASIC Stamp.

Upgrading from a radio tracker to a flight computer doesn't add much to the cost of avionics, but it does permit complex experiments and mission profiles that aren't available with a simple tracker. More information on flight computers is available from groups like ANSR, Project Traveler, or myself.

Your experiments will change on each mission, but your modules shouldn't. Give some thought to designing and building a generic style of airframe and flight computer. This way experiments are designed to meet the standards for the modules, rather than having modules designed to match the experiment. Be sure to document these standards. This is a much faster approach to flying missions, making failures less likely. Now your near spacecraft is more like a Space Shuttle than a Mercury space capsule. **NV**

Some Helpful Websites — Amateur Near Space Programs

ANSR
www.ansr.org
Arizona

EOSS
www.eoss.org
Colorado

HABITAT
habitat.netlab.org/index.shtml
Kansas

HamBONE
frodo.bruderhof.com/hambone/index.html
New York

KNSP (1)
www.ksu.edu/humec/knsp
Kansas

NSTAR
members.cox.net/mconner1/nstar.html
Nebraska

Project Traveler
www.rckara.org/project_traveler
Kansas

Ralph Wallio (2)
users.crosspaths.net/~wallio
Iowa

TVNSP
www.voiceofidaho.org/tvnsp
Idaho

Aware Electronics
www.aw-electronics.com
RM-60

Byonics
www.byonics.com
Tiny Trak III (TNC)

Garmin
www.garmin.com
GPS Receivers

HRO
www.hamradio.com
Amateur Radios

Kantronics
www.kantronics.com
KPC 3+ (TNC)

Kaymont
www.kaymont.com
Weather Balloons

Kaysam
www.kaysam.com
Weather Balloons

Parallax
www.parallax.com
BASIC Stamps

Rocketman
www.the-rocketman.com
Parachutes

APRS/Packet Radio
www.tapr.org
Packet Radio/APRS

ARRL
www.arrl.org
Amateur Radio Clubs

BIPOLAR TRANSISTOR COOKBOOK — PART 8

Ray Marston describes a miscellaneous collection of useful transistor circuits and gadgets in this month's final episode of an eight-part series.

by Ray Marston

The opening piece of this eight-part series described basic transistor principles and configurations; subsequent articles went on to describe a wide variety of practical transistor circuits ranging from common-collector amplifiers (Part 2), common-emitter and common-base amplifiers (Part 3), and small-signal audio amplifiers (Part 4), to various practical oscillator (Part 5), multivibrator waveform generator (Part 6), and audio power amplifier (Part 7) circuits. This month's final episode rounds off the "Transistor Cookbook" subject by presenting a miscellaneous collection of practical and useful transistor circuits and gadgets.

A NOISE LIMITER CIRCUIT

Unwanted electronic "noise" can be a great nuisance; when listening to very weak broadcast signals, for example, peaks of background noise often completely swamp the broadcast signal, making it unintelligible. This problem can often be overcome by using the noise limiter circuit in Figure 1. Here, the signal-plus-noise waveform is fed to amplifier Q1 via RV1. Q1 amplifies both waveforms equally, but D1 and D2 automatically limit the peak-to-peak output swing of Q1 to about 1.2 V. Thus, if RV1 is adjusted so that the signal output is amplified to this peak level, the noise peaks will not be able to greatly exceed the signal output, and intelligibility is greatly improved.

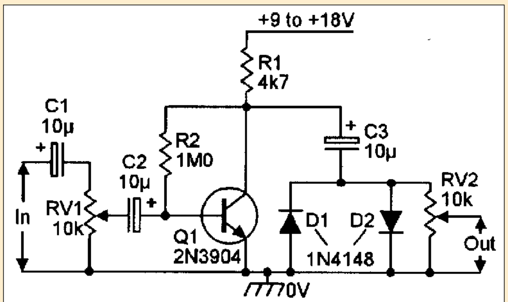


Figure 1. Noise limiter.

ASTABLE MULTIVIBRATOR CIRCUITS

The astable multivibrator circuit has many practical uses. It can be used to generate a non-symmetrical 800 Hz waveform that produces a monotone audio signal in the loudspeaker when S1 is closed (Figure 2). The circuit can be used as a Morse code practice oscillator by using a Morse key as S1; the tone frequency can be changed by altering the C1 and/or C2 values.

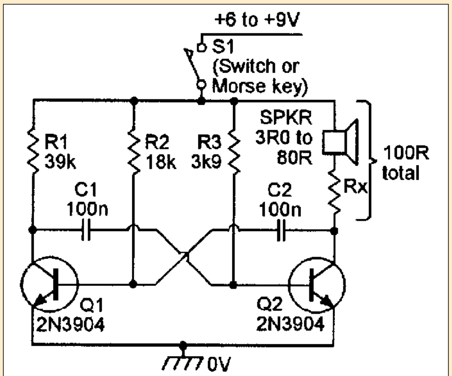


Figure 2. Morse code practice oscillator.

Figure 3 shows an astable multivibrator used as the basis of a "signal injector-tracer" item of test gear. When SW1 is in INJECT position 1, Q1 and Q2 are configured as a 1 kHz astable, and feed a good square wave into the probe terminal via R1-C1. This waveform is rich in harmonics, so if it is injected into any AF or RF stage of an AM radio, it produces an audible output via the radio's loudspeaker, unless one of the radio's stages is faulty. By choosing a suitable injection point, the injector can be used to trou-

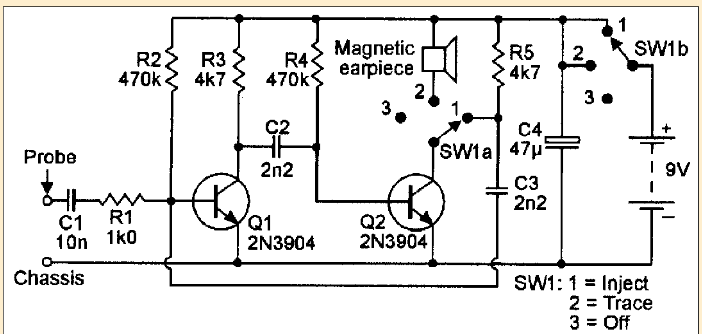


Figure 3. Signal injector-tracer.

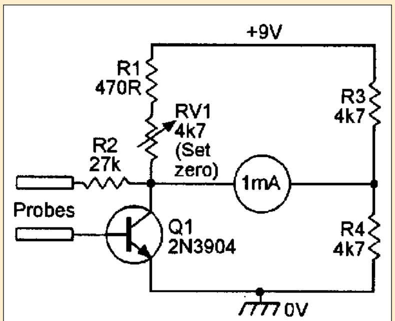


Figure 4. Simple lie detector.

ble-shoot a defective radio.

When SW1 is switched to TRACE position 2, the Figure 3 circuit is configured as a cascaded pair of common-emitter amplifiers, with the probe input feeding to Q1 base, and Q2 output feeding into an earpiece or head-set. Any weak audio signals fed to the probe are directly amplified and heard in the earpiece, and any amplitude-modulated RF signals fed to the probe are demodulated by the non-linear action of Q1. The resulting audio signals are then amplified and heard in the earpiece. By connecting the probe to suitable points in a radio, the tracer can thus be used to trouble-shoot a faulty radio, etc.

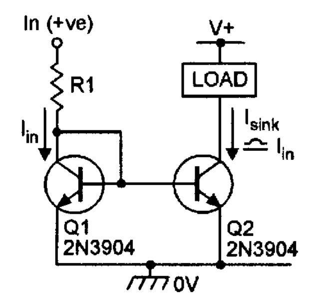


Figure 5. An npn current mirror.

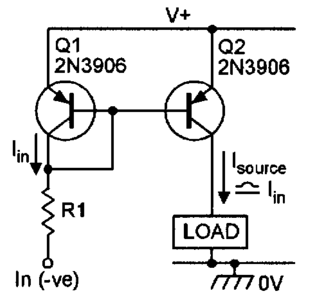


Figure 6. A pnp current mirror.

LIE DETECTOR

The lie detector of Figure 4 is an experimenter's circuit, in which the victim is connected (via a pair of metal probes) into a Wheatstone bridge, formed by R1-RV1-Q1 and R3-R4; the 1 mA center-zero meter is used as a bridge-balance detector. In use, the victim makes firm contact with the probes and, once he/she has attained a relaxed state (in which the skin resistance reaches a stable value), RV1 is adjusted to set a null on the meter. The victim is then cross-questioned and, according to theory, the victim's skin resistance will then change, causing the bridge to go out of balance if he/she lies or shows any sign of emotional upset (embarrassment, etc.) when being questioned.

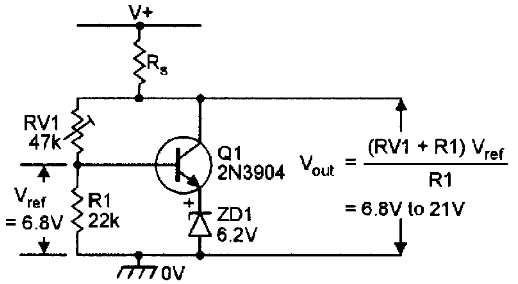


Figure 7. Adjustable zener.

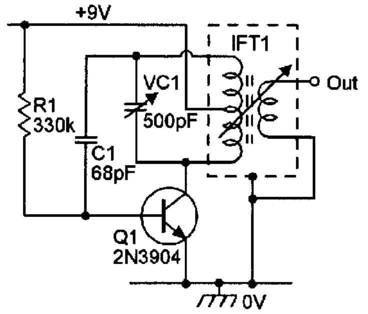


Figure 8. MW signal generator/BFO.

CURRENT MIRRORS

A current mirror is a constant-current generator in which the output current magnitude is virtually identical to that of an independent input control current. This type of circuit is widely used in modern linear IC design. Figure 5 shows a simple current mirror using ordinary npn transistors; Q1 and Q2 are a matched pair and share a common thermal environment.

When input current Iin is fed into diode-connected Q1, it generates a proportionate forward base-emitter voltage, which is applied directly to the base-emitter junction of matched transistor Q2, causing it to sink an almost identical (mirror) value of collector current, I_{sink}. Q2 thus acts as a constant current sink that is controlled by I_{in}, even at collector voltages as low as a few hundred millivolts.

Figure 6 shows a pnp version of the simple current mirror circuit. This works in the same basic way as already described, except that Q2's collector acts as a constant current source that has its amplitude controlled by I_{in}. Note that both of these circuits still work quite well as current-controlled, constant-current sinks or sources, even if Q1 and Q2 have badly matched characteristics, but in this case may not act as true current mirrors, since their I_{sink} and I_{in} values may be very different.

AN ADJUSTABLE ZENER

Figure 7 shows the circuit of an adjustable zener that can have its output voltage pre-set over the range 6.8 V to 21 V via RV1. The circuit action is such that a fixed reference voltage (equal to the sum of the zener and V_{be} values) is generated between Q1's base and ground (because of the value of zener voltage used) and has a near-zero temperature coefficient. The circuit's output voltage is equal to V_{ref} multiplied by (RV1 + R1)/R1, and is thus pre-settable via RV1. This circuit is used like an ordinary zener diode, with the R_S value chosen to set its operating current at a nominal value in the range 5 to 20 mA.

L-C OSCILLATORS

L-C oscillators have many applications in test gear and gadgets, etc. Figure 8 shows an L-C medium-wave (MW) signal generator or beat-frequency oscillator (BFO), with Q1 wired as a Hartley oscillator that uses a modified 465 kHz IF transformer as its collector load. The IF transformer's internal tuning capacitor is removed, and variable oscillator tuning is available via VC1, which enables the output frequency (on either fundamentals or harmonics) to be varied from well below 465 kHz to well above 1.7 MHz. Any MW radio will detect the oscillation frequency if placed near the circuit; if the unit is tuned to the radio's IF value, a beat note will be heard, enabling CW and SSB transmissions to be clearly heard.

Figure 9 shows the above oscillator modified so that,

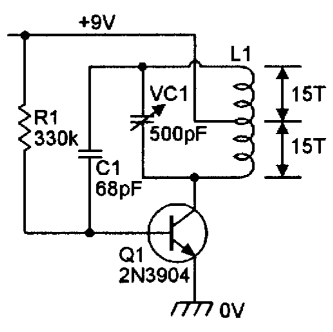


Figure 9. Metal/pipe locator.

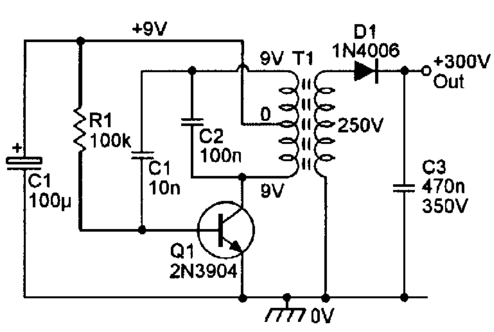


Figure 10. 9 V to 300 V DC-to-DC converter.

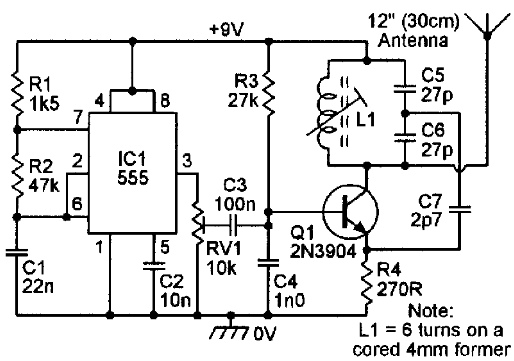


Figure 11. FM radio transmitter alarm.

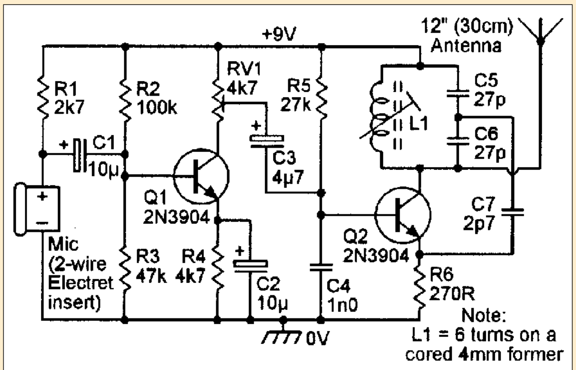


Figure 12. FM microphone/bug transmitter.

when used in conjunction with a MW radio, it functions as a simple metal/pipe locator. Oscillator coil L1 is hand-wound and comprises 30 center-tapped turns of wire, firmly wound over about a 25 mm (one-inch) length of a 75 to 100 mm (three- to four-inch) diameter non-metallic former or search head and connected to the main circuit via a three-core cable. The search head can be fixed to the end of a long non-metallic handle if the circuit is to be used in the classic metal detector mode, or can be hand-held if used to locate metal pipes or wiring hidden behind plasterwork, etc. Circuit operation relies on the fact that L1's electromagnetic field is disturbed by the presence of metal, causing the inductance of L1 and the frequency of the oscillator to alter. This frequency shift can be detected on a portable MW radio placed near L1 by tuning the radio to a local station and then adjusting VC1 so that a low frequency beat or whistle note is heard from the radio. This beat note changes if L1 (the search head) is placed near metal.

Figure 10 shows another application of the Hartley oscillator. In this case, the circuit functions as a DC-to-DC converter, which converts a 9 V battery supply into a 300-V DC output. T1 is a 9V-0-9V to 250 V transformer, with its primary forming the L part of the oscillator. The supply voltage is stepped up to about 350 V peak at T1 secondary, and is half-wave rectified by D1 and used to charge C3. With no permanent load on C3, the capacitor can deliver a powerful but non-lethal belt. With a permanent load on the output, the output falls to about 300 V at a load current of a few mA.

FM TRANSMITTERS

Figures 11 and 12 show a pair of low-power FM transmitters that generate signals that can be picked up at a respectable range on any 88 to 108 MHz FM-band receiver. The Figure 11 circuit uses IC1 as a 1 kHz squarewave generator that modulates the Q1 VHF oscillator, and produces a harsh 1 kHz tone signal in the receiver; this circuit thus acts as a simple alarm-signal transmitter.

The Figure 12 circuit uses a two-wire electret microphone insert to pick up voice sounds, etc., which are amplified by Q1 and used to modulate the Q2 VHF oscillator; this circuit thus acts as an FM microphone or bug. In both circuits, the VHF oscillator is a Colpitts type, but with the transistor used in the common-base mode and C7 giving feedback from the tank output back to the emitter input.

These two circuits have been designed to conform to American FCC regulations, and they thus produce a radiated field strength of less than 50 µV/m at a range of 15 meters (15 yards), and can be freely used in the USA. It should be noted, however, that their use is quite illegal in many countries, including the UK.

To set up these circuits, set the coil slug at its middle position, connect the battery, and

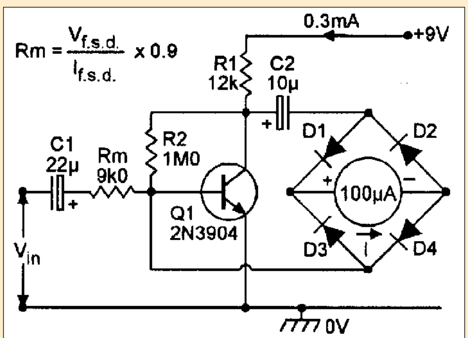


Figure 13. The frequency response of this 1 V AC meter is flat to above 150 kHz.

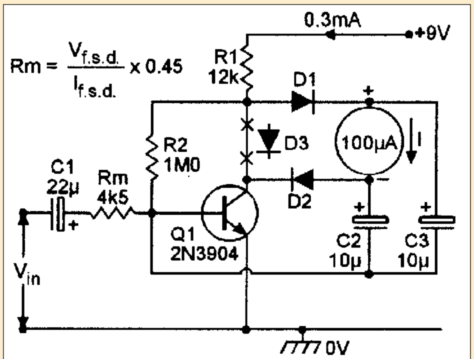


Figure 14. Pseudo full-wave version of the 1 V AC meter.

tune the FM receiver to locate the transmitter frequency. If necessary, trim the slug to tune the transmitter to a clear spot in the FM band. RV1 should then be trimmed to set the modulation at a clean level.

TRANSISTOR AC VOLTMETERS

An ordinary moving-coil meter can be made to read AC voltages by feeding them to it via a rectifier and suitable multiplier resistor, but produces grossly non-linear scale readings if used to give FSD values below a few volts. This non-linearity problem can be overcome by connecting the meter circuitry into the feedback loop of a transistor common-emitter amplifier, as shown in the circuits of Figures 13 to 15, which (with the Rm values shown) each read 1 V FSD.

The Figure 13 circuit uses a bridge rectifier type of meter network, and draws a quiescent current of 0.3 mA, has an FSD frequency response that is flat from below 15 Hz to above 150 kHz, and has superb linearity up to 100 kHz when using IN4148 silicon diodes or to above 150 kHz when using BAT85 Schottky types. R1 sets Q1's quiescent current at about treble the meter's FSD value, and thus gives the meter automatic overload protection.

Figures 14 and 15 show pseudo full-wave and ghosted half-wave versions of the above circuit. These have a performance similar to that of Figure 13, but with better linearity and lower sensitivity. D3 is sometimes used in these circuits to apply slight forward bias to D1 and D2 and thus enhance linearity, but this makes the meter pass a standing current when no AC input is applied. The diodes used in these and all other electronic AC meter circuits shown in this article should be either silicon (IN4148, etc.) or (for exceptionally good performance) Schottky types; germanium types should not be used.

In the circuits in Figures 13 to 15, the FSD sensitivity is set at 1 V via Rm, which can not be reduced below the values shown without incurring a loss of meter linearity.

The Rm value can, however, safely be increased, to give higher FSD values, e.g., by a factor of 10 for 10 V FSD, etc.

If greater FSD sensitivity is wanted from the above circuits, it can be obtained by applying the input signal via a suitable pre-amplifier, i.e., via a +60 dB amplifier for 1 mV sensitivity, etc. Figure 16 shows this technique applied to the Figure 13 circuit, to give an FSD sensitivity variable between 20 mV and 200 mV via RV1. With the sensitivity set at 100 mV FSD, this circuit has an input impedance of 25 K and a bandwidth that is flat within 0.5 dB to 150 kHz.

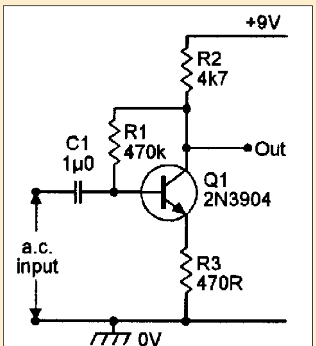


Figure 18. This x10 wideband pre-amplifier is used to boost an AC millivoltmeter's sensitivity.

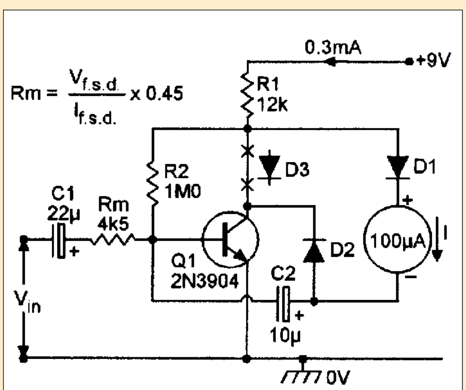


Figure 15. Ghosted half-wave version of the 1 V AC meter.

AC MILLIVOLTMETER CIRCUITS

A one-transistor AC meter cannot be given an FSD sensitivity greater than 1 V without loss of linearity. If greater sensitivity is needed, two or more stages of transistor amplification must be used. The highest useful FSD sensitivity that can be obtained (with good linearity and gain stability) from a two-transistor circuit is 10 mV, and Figure 17 shows an excellent example that gives FSD sensitivities in the range 10 mV to 100 mV (set via Rx). It uses D1 and D2 in the "ghosted half-wave" configuration, and its response is flat within 0.5 dB to above 150 kHz; the circuit's input impedance is about 120 K when set to give 100

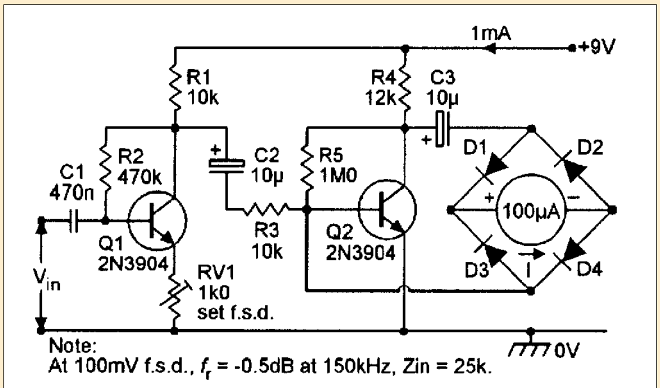


Figure 16. This AC voltmeter can be set to give FSD sensitivities in the range 20 mV to 200 mV.

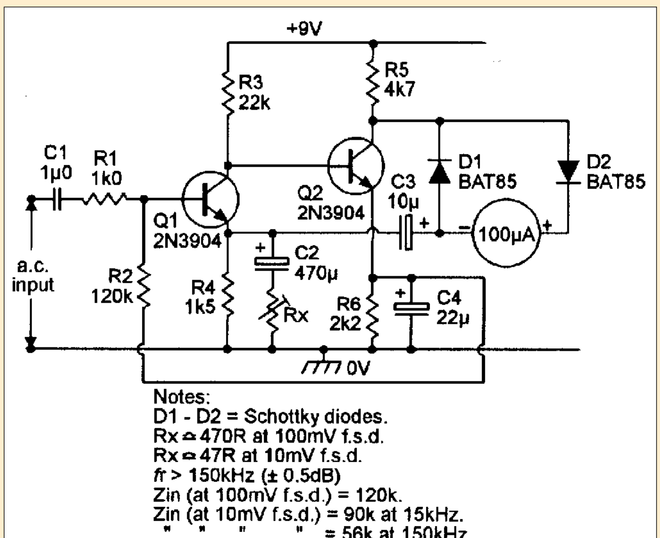


Figure 17. Wideband AC millivoltmeter with FSD sensitivity variable from 10 mV to 100 mV via Rx.

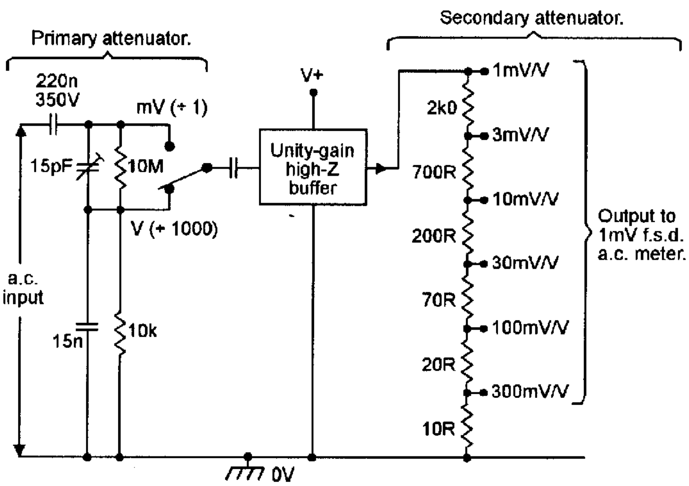


Figure 19. Basic multi-range AC volt/millivolt meter circuit.

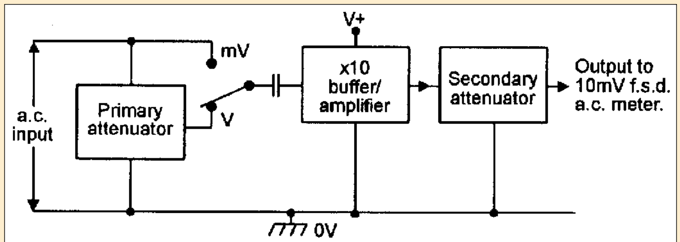


Figure 20. A useful AC volt/millivolt meter circuit variation.

mV FSD sensitivity (Rx = 470 Ohms); when set to give 10 mV sensitivity (Rx = 47 Ohms), the input impedance varies from 90 K at 15 kHz to 56 K at 150 kHz.

Figure 18 shows a simple x10 preamplifier that can be used to boost the above circuit's FSD sensitivity to 1 mV; this circuit has an input impedance of 45 K and has a good wideband response. Note, when building highly sensitive AC millivoltmeters, great care must be taken to keep all connecting leads short, to prevent unwanted RF pickup.

A wide-range AC volt/millivolt meter can be made by feeding the input signals to a sensitive AC meter via suitable attenuator circuitry. To avoid excessive attenuator complexity, the technique of Figure 19 is often adopted; the input is fed to a high-impedance unity-gain buffer, either directly (on "mV" ranges) or via a compensated 60 dB attenuator (on V ranges), and the buffer's output is fed to a basic 1 mV FSD meter via a simple low-impedance attenuator, which in this example has 1-3-10, etc., ranging.

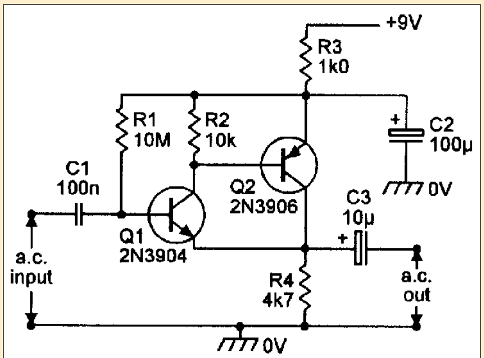


Figure 21. Unity-gain input buffer.

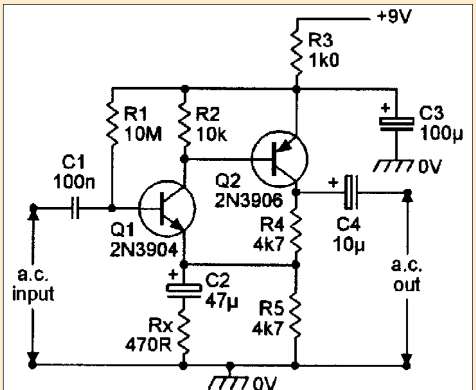


Figure 22. Buffer with x10 gain.

Note, when using this circuit that its input-to-unity-gain-buffer-output frequency response is virtually flat over the (typical) frequency range 20 Hz-150 kHz when used on the "mV" ranges, and that the primary attenuator's 15 pF trimmer must — when initially setting up the circuit — be adjusted on test to obtain the same frequency response on the basic "V" range.

Figure 20 shows a useful variation of the above technique. In this case, the input buffer also serves as a x10 amplifier, and the secondary attenuator's output is fed to a meter with 10 mV FSD sensitivity, the net effect being that a maximum overall sensitivity of 1 mV is obtained with a minimum of complexity.

Figures 21 and 22 show input buffers suitable for use with the above types of multi-range circuits. The Figure 21 design is that of a unity-gain buffer; it gives an input impedance of about 4.0 M. The Figure 22 buffer gives a x10 voltage gain (set by the R1/Rx ratio) and has an input impedance of 1.0 M. **NV**

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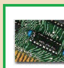

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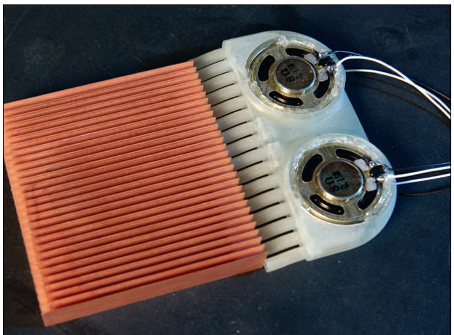

Close-up of a prototype synthetic jet (SynJet). Vibrating diaphragms (on right) produce trains of turbulent air puffs that flow out of the white tubes and into the cooling fins of the electronic device. Photo by Gary Meek, courtesy of Georgia Tech.

You have probably noticed that today's microprocessors and other devices have presented designers with thermal management problems in recent years.

The traditional approach has been to simply employ larger heatsinks and more powerful fans. However, heatsinks can take up a lot of space, and cooling fans have mechanical limitations.

For example, much of the circulated air bypasses the heatsinks and does not mix well with the thermal boundary layer that forms on the fins. Fans placed directly above heatsinks have "dead areas" where their motor assemblies block air flow.

And, as designers boost air flow to increase cooling, fans use more energy, create more noise, and take up more space. Researchers at the Georgia Institute of Technology (**www.gatech.edu**) have concluded that conventional fan-driven cooling is incompatible with future high-density, low-power systems and therefore have been working on alternative solutions. A concept that seems to have great potential is their patented synthetic jet (SynJet) device. The operating principle is simple. Perhaps you have demonstrated the amazing power of your stereo system by letting the "woofer" blow out a lighted match.

In much the same manner, the SynJet uses an electromagnetic or piezoelectric driver, vibrating at a rate of 100 to 200 Hz, to suck in and then expel air from a cavity.

This creates pulsating jets that are directed to precise locations where cooling is needed. According to the inventors, the device is better than a fan in that it has no friction parts to wear out, uses less energy, and creates less noise. They point out that, although the jets move 70 percent less air than fans of comparable size, "the air flow they produce contains tiny vortices which make the flow turbulent, encouraging efficient mixing with ambient air and breaking up thermal boundary layers. You get a much higher heat transfer coefficient with synthetic jets, so you do away with the major cooling bottleneck seen in conventional systems." Furthermore, "The ability to scale the jet modules to suit specific applications and to integrate them into electronic equipment could provide cooling solutions over a broad range of electronic hardware ranging from desktop computers to mobile phones, and other portable devices that are now too small or have too little power for active cooling."

Plastic Memories May Offer High-Density Storage

Engineers at Princeton University (**www.princeton.edu**) and Hewlett-Packard (**www.hp.com**) have discovered a combination of materials that could lead to cheap and super-compact electronic memory devices for archiving digital images or other data. The invention could result in a single-use memory card that permanently stores data and is faster and easier to use than a compact disk. The device could be very small, because it would not involve moving parts such as the laser and motor drive required by CDs. The concept is based on polyethylenedioxythiophene (PEDOT), a polymer material that is clear and electrically conductive. It has been used for years as an antistatic coating on photographic film, and more recently as an electrical contact on video displays that require light to pass through the circuitry. PEDOT conducts electricity at low voltages but permanently loses its conductivity when exposed to higher voltages (and thus higher currents), making it act like a fuse or circuit breaker. This led the researchers to think about using PEDOT as a way of storing digital information. As we all know, digital images and computer data are stored as long strings of ones and zeroes. A PEDOT-based memory device would have a grid of circuits in which all the connections contain a PEDOT fuse. A high voltage could be applied to any of the contact points, blowing that particular fuse and leaving a mix of working and nonworking circuits. These open or closed connections would represent

zeros and ones and would become permanently encoded in the device. A blown fuse would block current and be read as a zero, while an unblown fuse would let current pass and act as a one. This grid of memory circuits could be made so small that, based on the test junctions the researchers made, one million bits of information could fit in a square millimeter of paper-thin material. If formed as a block, the device could store more than 1 GB of information, or about 1,000 high-quality images, in a volume of 1 cc. The concept is said to be about five years from commercial development.

Computers and Networking

Artificial Intelligence Research Continues

We haven't heard much about artificial intelligence (AI) lately, but it appears that some serious research continues in an effort to achieve this holy grail of computer science. Artificial Development, Inc. (**www.ad.com**), recently announced that it has completed assembly of the first functional portion of a prototype of its CCortex, a 20-billion-neuron emulation of the human cortex, which it will use to build a next-generation artificial intelligence system. The cluster is a high-performance, parallel supercomputer, composed of 500 nodes and 1,000 processors, 1.5 terabytes of RAM, and 80 terabytes of storage. The software/hardware system runs on Linux, using Intel and AMD processors. When all sections are assembled, CCortex is expected to reach a theoretical peak performance of 4,800 Gflops, making it one of the top 20 fastest computers in the world. The cluster will be used as a test bed for beta versions of CCortex. CCortex is a massive spiking neuron network emulation that will mimic the human cortex — the outer layer of gray matter at the cerebral hemispheres, largely responsible for higher brain functions. The emulation covers up to 20 billion layered neurons and 2 trillion 8-bit connections. Most neural network models to date have been based on the Hebbian network,

The first CCortex cluster. Courtesy of Artificial Development, Inc.

a simplified version of the real neural networks, based exclusively on connectivity properties between neurons. CCortex adds to classical Hebbian connections a time-sensitive, analog representation of the shape of "spikes," the pulsing patterns that enable neuron populations to communicate with each other. This allows CCortex to tune vast populations of neurons and the information they hold to complex spiking patterns, adding a higher level of complexity to a highly realistic simulation.

The CCortex software emulation applies its Spiking Neuron Software Engine to a database that has a representation of the layered distribution of neural nets and detailed interconnections in the brain. The data closely emulates specialized regions of the human cortex, corpus callosum, anterior commissure, amygdale, and hippocampus. The emulation aims to actualize the estate of each neuron and its connections several times per second, maintaining a myriad of competing spiking patterns, while providing feedback and limited interaction with simplified versions of other nervous and sensory systems.

Another Spam Defense

According to a Reuters news report, Yahoo (**www.yahoo.com**) is intending to introduce a software product called "Domain Keys" that will assist developers of the Web's major open-source Email software and systems (including Yahoo itself) in reducing the current plague of unsolicited commercial messages ("spam"). According to the report, this technology would make a slight change in the way Email works by embedding a secure, private key in all message headers. A receiving system would compare this private key with the presumed sender's Internet's Domain Name System's public key. If the public key can decrypt the private key, this will prove that the return header is not forged, and it will be delivered. If not, the message will be dumped. As with all proposed spam cures, whether technological or legislative, the plan cannot totally eliminate the problem unless it is universally adopted, which is highly unlikely.

However, according to a Yahoo representative, "If we can get only a small percentage of the industry to buy in, we think it can make a dent." In addition, Domain Keys is free and comes with no use restrictions, so there is no overwhelming reason why an Email provider should not adopt it.

Circuits and Devices

VGA Image Sensor Introduced

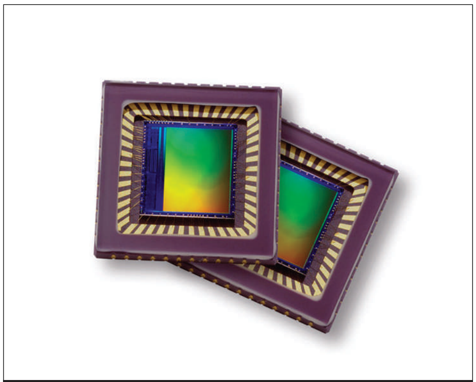

Image sensor provides full-resolution operation at 200 frames per second. Photo courtesy of Micron Technology, Inc.

Micron Technology, Inc. (**www.micron.com**), has announced the MT9V403 high-speed VGA image sensor, which is capable of operating at up to 200 frames per second (fps) at full resolution. Using Micron's proprietary TrueSNAP™ technology, it features a freeze-frame electronic shutter that stops fast motion with high accuracy. TrueSNAP technology was created for use in high-speed applications that allow all pixels to be simultaneously exposed, similar to the "global shutter" of a CCD sensor. The device's digital interface provides flexible control of performance parameters such as exposure time, frame rate, and windowing functionality. The sensor includes on-chip 10-bit analog-to-digital converters outputting monochrome or color digital video in 659H-by-494V-pixel format at 0-200 fps and a responsivity of 2,000 bits per lux second. Currently, the MT9V403 is designed for high-speed machine-vision and special effects applications, including such things as airbag deployment and golf swing analysis. It is intended that the TrueSNAP technology will eventually migrate to other Micron imaging devices.

Low-Cost Temperature Switch

Maxim Integrated Products (**www.maxim-ic.com**), has introduced the MAX6516-MAX6519 line of low-cost, analog temperature switches that assert a logic signal when a preset temperature is reached. The devices feature ±0.5°C typical accuracy while consuming only 20 µA of supply current. Temperature trip thresholds are factory set and available from +35°C to +115°C, in 10°C increments. Hysteresis is pin selectable at 2°C or 10°C. No external components are required to set the trip threshold. These temperature switches are designed for over/undertemperature regulation, desktop and notebook computers, RAID, and servers. The MAX6516/MAX6518 provides an active-high, push-pull output. The MAX6517/MAX6519 provides an active-low, open-drain output. Each device also features an analog output with an accuracy of ±3°C (max) over the entire temperature range. The devices operate over a temperature range of -40°C to +125°C, with a power-supply voltage range of 2.7 to 5.5 V. They are available in a five-pin SOT23 package. Prices start at $0.75 in quantities of 2500+.

Industry and the Profession

Museum of Hard Disc Drives Planned

Forget about the Louvre, the Hermitage, or the Prado. Don't bother with the Smithsonian, the American Museum of Science and Energy, or England's National Museum of Science and Industry. Put all your travel plans on hold, because the Museum of Hard Disc Drives will be opening during the 2004 Komputer Expo Fair in (no jokes, please) Warsaw, Poland. After the fair, the exhibits will be transferred to the Silesian Museum in Katowice for viewing by the general public and, eventually, transferred to the headquarters of MBM

Among the vintage drives to be displayed in the Museum of Hard Disc Drives is the classic Seagate ST225. Photo courtesy of Randolph Byrnes.

Ontrack (**www.mbm.com.pl**), the data recovery company that came up with the idea. According to a press release, the Museum of Hard Disc Drives "will popularize the history of dynamic development of informatics among PC users."

Three of the items on display were magnanimously donated by Seagate Technology (**www.seagate.com**): ST4038, ST225, and ST125 drives. Developed in 1985, the ST4038 was used in the IBM PC AT and had a capacity of 38 MB.

According to Marcin Musil, managing director of MBM Ontrack, "We are glad that our initiative has gained the support of the biggest manufacturer of hard disc drives. The drives donated to the Museum by Seagate are the most precious exhibits of our collection." "Precious," of course, is a relative term.

As I write this, a vintage ST225 drive and controller card is for sale on Ebay with an initial price of $10.00, so far attracting no bids. Perhaps our readers can provide additional assistance.

If anyone from the museum reads this, please note that I am willing to donate a magnificent 44 MB Syquest cartridge from my private collection (as long as I don't have to pay the postage). It's great for propping up a wobbly table, and I would rate its current value at nearly $1.37.

HP Continues to Gain Workstation Market Share

Hewlett-Packard (**www.hp.com**) captured 27 percent of the worldwide workstation market for units shipped for the third quarter of calendar year 2003, according to a report released recently by research group IDC. In the US personal workstation segment, HP grew at twice the rate of the overall market with a 17.5 percent increase.

HP recognized year-to-year growth in the same market with an increase of 24 percent, leading all other workstation vendors ranked by IDC. In Western Europe, HP continues to be the no. 1 workstation provider with sequential growth of 24 percent.

HP recognized the most growth within the Intel® Pentium® 4 and Xeon based personal workstation segment, but it increased units shipped across its entire workstation line. **NV**

by Mark Balch

Basics For Beginners

Just For Starters

Choosing A 7400 Logic Family

Engineers and hobbyists alike have taken advantage of the ubiquitous 7400-series logic families for years. A 7400 device comes to mind when you need a single AND gate, a flip-flop, or other basic logic function. These devices are easy to use because of their standardized features. Across different families, equivalent devices generally have identical pin assignments and basic functionality. 7400 logic is a de-facto standard that everyone designing with electronics should be familiar with.

There have been many families under the 7400 canopy that have come and gone. Some existing families are just a few years old and others are counting decades. In this column, we'll discuss a few of the more commonly used 7400 families. Once you understand the areas of distinction, you'll be able to do your own research to find the family most suited to your project.

IC Specifications

Integrated circuit (IC) manufacturers provide many specifications for their products. The specifications that define different 7400 variants are essentially nominal supply voltage, input/output voltages and currents, and propagation delays. Supply voltage is historically denoted V_{CC}, referring to the collector voltage of transistors in the original devices. Manufacturers sometimes rate V_{CC} at ± 10%, but often specify electrical characteristics under a tighter ± 5% range.

Voltage specifications are treated differently for each logic level. When a logic-0 is applied to an IC input, the specification that really matters is the maximum allowable voltage level that can be recognized as a 0 by the IC. This specification can be denoted as $V_{IL(MAX)}$. Conversely, a logic-1 specification is the minimum voltage level that can be recognized as a 1, or $V_{IH(MIN)}$. Between $V_{IL(MAX)}$ and $V_{IH(MIN)}$ lies a "no-man's land" that should be avoided due to indeterminate results.

Similar voltage specifications apply to IC outputs. You are interested in the maximum, or worst-case, output voltage that represents a logic-0, $V_{OL(MAX)}$. If $V_{OL(MAX)}$ is higher than $V_{IL(MAX)}$, you won't be able to reliably drive a similar chip. Of equal interest is the worst-case logic-1 output voltage, $V_{OH(MIN)}$. $V_{OH(MIN)}$ cannot be less than $V_{IH(MIN)}$ for reliable inter-chip connections.

Currents are signed specifications because currents flow into and out of the IC depending on the logic level being applied or driven. The convention is that positive currents enter the chip and negative currents leave the chip. On the input side, the logic-0 input current is actually negative because current flows out of the chip to a lower applied voltage. Logic-1 output current is also negative because current flows out of the chip. An IC "sinks" incoming currents and "sources" outgoing currents. Written specifications may simplify notation by referring to currents in absolute values, thereby foregoing mention of negative currents.

It should be noted that, as a load requires more current, the output voltage is pulled towards the center "no-man's land." A lightly loaded output will exhibit a more desirable voltage level closer to either of the IC's power rails. The output voltage specifications can no longer be guaranteed if you exceed a device's specified output current rating.

Propagation Delay

The parameters just mentioned are called DC specifications because they refer to steady-state operation of the IC. An output voltage will not change if all circuit characteristics are held constant. Propagation delays are AC specifications because they refer to transitional behavior. An IC's output voltage changes some finite time after a corresponding input voltage changes. This is a propagation delay, generally measured in nanoseconds, or in billionths of a second.

Manufacturers should specify minimum and maximum propagation delays, but they do not always do so. Often, only the maximum propagation delay is specified, which is adequate for many circuits. Some circuits — especially high-speed circuits — also require minimum delays. When these specifications are unavailable, it takes experience and care to avoid timing problems. Timing analysis is a detailed topic beyond the scope of

this article. My book, *Complete Digital Design*, contains an in-depth presentation of timing analysis.

Watch out for the trap of "typical" timing specifications that many IC data sheets provide. Typical numbers are not worst-case specifications over the IC's specified operating range. Propagation delays change dramatically with changes in supply voltage and temperature. Minimum and maximum specifications are guaranteed across an operating range. However, typical numbers can help provide a clearer picture of a device's operation. Just don't get fooled into relying on them alone.

Device	V_{CC} (nominal)	$I_{IH(MAX)}$ (mA)	$\lvert I_{IL(MAX)}\rvert$ (mA)	$V_{IH(MIN)}$	$V_{IL(MAX)}$	$\lvert I_{OH(MAX)}\rvert$ (mA)	$I_{OL(MAX)}$ (mA)	$V_{OH(MIN)}$	$V_{OL(MAX)}$	$t_{PROP(MAX)}$ (ns)
74LS00	5.0	0.02	0.36	2	0.8	0.4	8	2.7	0.5	15
74F00	5.0	0.005	0.6	2	0.8	1	20	2.7	0.5	5
74HCT00	5.0	0.001	0.001	2	0.8	4	4	3.98	0.26	23
74ACT00	5.0	0.001	0.001	2	0.8	24	24	3.86	0.44	9
74LC	3.3	0.005	0.005	2	0.8	24	24	2.2	0.55	5.2
	2.5	0.005	0.005	1.7	0.7	8	8	1.8	0.6	6.2

TABLE 1: Basic 7400 family DC and AC characteristics (source: Fairchild Semiconductor)

Bipolar (TTL)

Now that you know how to evaluate an IC's characteristics, let's get back to 7400 devices. The original 7400 families are bipolar devices, also known as transistor-transistor logic (TTL). Bipolar logic is constructed from bipolar junction transistors, in contrast to CMOS logic, which is constructed using a metal-oxide semiconductor (MOS) process. Two of the common bipolar families still in use today are 74LS and 74F. 74LS uses low-power Schottky circuitry while 74F uses faster circuitry at the expense of higher power consumption.

Both families run on a single 5 V (nominal) power supply. The 74LS and 74F families are available from almost every electronics component retailer and distributor. Table 1 lists DC and AC characteristics for the families mentioned in this article. The '00 device in each family is a quad two-input NAND-gate. You can see that the 74LS00 is much slower than the 74F00 and that it provides less output current. A characteristic of TTL logic is the asymmetric drive strength between logic-1 and logic-0. The logic-0 state can sink much more current than the logic-1 state can source.

On the input side, the logic-0 state sources more current than the logic-1 state sinks. 74LS and 74F devices can be mixed because they have compatible input and output voltage thresholds. There are 0.7 V of worst-case margin between $V_{OH(MIN)}$ and $V_{IH(MIN)}$ and 0.3 V between $V_{OL(MAX)}$ and $V_{IL(MAX)}$.

Fan-out

Fan-out is an important characteristic to pay attention to: it determines the number of inputs that a single output can drive. From a purely DC perspective, fan-out is calculated by dividing the output drive strength by the input current for each logic state. Then you take the lesser of the two numbers. Doing this for the 74LS00 and 74F00 yields 22 and 33, respectively. However, fan-out should also be considered from an AC, or transitional, perspective.

Each additional load on an output driver adds a small amount of capacitance. An IC pin typically adds about 10 pico-Farads (pF) of capacitance (some more

and some less). Capacitors take a finite time to charge and slow down the rise and fall times of an IC's output driver. AC specifications, such as propagation delays, are often accompanied with a maximum load capacitance. Values from 20 to 50 pF are typical. A rough fan-out estimate is obtained by dividing the maximum capacitance by 10 pF. This drops the fan-out to just several inputs rather than 20 or 30.

If an IC has much faster AC specifications than your application requires, you may experiment with higher fan-out than what is actually allowed by the capacitance numbers. It is important to understand the compromise being made.

CMOS Logic

Complementary MOS (CMOS) logic is a lower power alternative to bipolar. Several CMOS 7400 families were developed to complement the TTL variants. Some families such as C and HC are function-compatible with TTL, but have different voltage thresholds. Different thresholds make it difficult to mix different technologies on the same circuit board. 74HCT was developed for the low-power benefits of CMOS while retaining TTL-compatible voltage thresholds.

As seen in Table 1, HCT has lower input current than 74LS and 74F, which enables it to consume less power at steady-state. (Capacitance dominates power consumption during signal transitions due to the charge/discharge process.) 74HCT also has symmetrical output drive strength.

Table 1 shows that 74HCT is slower than 74LS and 74F. 74ACT increases the speed and drive strength of CMOS logic, though it is not as fast as 74F. Both CMOS variants do a better job than TTL of driving outputs closer to the power rails.

Low-Voltage Devices

Discrete logic has taken a diminished role in mainstream system design due to high-density ICs. More and more systems have abandoned 5-volt logic in favor of 3.3, 2.5, 1.8, and 1.5-volt technologies. The 7400 family has been energized in recent years by new variants from several manufacturers. Fairchild Semiconductor offers the 74LCX family that operates at lower supply voltages with relatively fast propagation delays.

Which Family to Pick?

Choosing a logic family is highly application specific. If you are prototyping with mature technologies, 5-volt logic may be appropriate. The next aspect to consider is how fast your ICs need to operate. Generally speaking, it is best to use slower devices with lower power consumption whenever possible.

Slower devices have fewer tricky problems and it is easier to work with lower currents. Then there are handling concerns of CMOS versus TTL. CMOS devices are sensitive to static electricity.

If you're not careful, you can zap a chip and destroy it. Finally, the choice may be made for you by the other devices that you are working with. If you need to work with a 3.3-volt IC, you'll have to pick a low-voltage family. **NV**

About the Author

Mark Balch is the author of *Complete Digital Design* (see **www.completedigitaldesign.com**) and works in the Silicon Valley high-tech industry. His responsibilities have included PCB, FPGA, and ASIC design. Mark has designed products in the fields of telecommunications, HDTV, consumer electronics, and industrial computers. In addition to his work in product design.

Mark has actively participated in industry standards committees and has presented work at technical conferences. Mark holds a bachelor's degree in electrical engineering from The Cooper Union in New York City. He can be reached via Email at mark@completedigitaldesign.com.

Continued from Page 6

saddened by the apparent lack of interest in circuit basics by the current pocket-protector generation. Mr. Frenzel did a splendid job of explaining just what has happened over the past 30+ years, and, to some extent, has allayed my fears that the electronics enthusiast will become an absolute slave to off-the-shelf technology.

Nuts & Volts continues to present a broad spectrum of interesting articles, which I hope will continue. Ray Marston's series on bipolar transistors, Chris Hannold's introduction to FPGAs, and even Don Stulken's letter in “Reader Feedback” (including *Nuts & Volts* kind offer to distribute Don's circuits and notes) help not only to maintain an interest in electronics basics, but to prove that interest does, indeed, continue to exist at this level. I will always maintain that a grounding in basics is essential, for, as the quote implies, "Those who cannot remember the past are condemned to repeat it."

Jim Wood
via Internet

Dear Nuts & Volts:

I greatly appreciate and enjoy your publication. As an electronics student and hobbyist, I thank you and all your contributing editors. I've learned more from your publication than in the 18 months of tech-school that I attended (for a great deal of money!). We live and learn.

Thank you, God bless, and keep up the good work!

Freddy R. Lazzu
Greensburg, PA

The Business of Electronics Through Practical Design and Lessons Learned

In The Trenches

Being Successful

Everyone wants to succeed. But, some people are better at it than others. Is it really the person? Or is it how they address their objectives? We'll look at the skills needed to be successful. And, we'll see that anyone can improve their success rate once they understand the steps for success.

What is Success?

A while back, I was one of a number of people asked to participate in a "Career Day" at a local high school. Before each of us started to discuss our particular area of interest, the principal addressed the students and defined success in terms of four clear and simple steps: 1. Define a goal; 2. Decide what you want to spend to get that goal; 3. Make a plan; and 4. Execute the plan. I was surprised to realize that I'd been saying those same things (but with much less eloquence).

However, before we start on these steps, there is an important point that has to be made. Success is a subjective measure. Success is what *you* think it is ... not what someone else thinks. You don't have to get straight A's to be a successful student. You don't have to make billions of dollars to be successful in business. You are a success if you think and feel you are. (Of course, this doesn't preclude others from trying to change your mind.) Remember, success is achieving *your* goal, not someone else's goal.

Defining a Goal

The first step is probably the most direct and simple. Nevertheless, it seems to be overlooked with regularity. It's just defining what you want. Naturally, there are many things you want. Some are general like fame and fortune. Others are more specific like getting a raise or a promotion. It's important to know precisely what you want.

Unfortunately there are a fair number of people who want to be successful but don't really have any goals. These people are really walking through life without any direction. They think that if they go to work each day and do their job that, in the end, they'll be a vice president of the company. Unfortunately, this is not a very likely outcome.

These people are depending on others to bestow success on them. Success is not something given by others, it is something you craft for yourself. Let's be realistic, if you had to choose between giving a promotion to yourself or some other worker, you'd most likely choose yourself. Being selfish is human nature, and there's nothing wrong with that (within reasonable limits). Everyone wants to win.

It's important to choose a reasonable goal. I'm 5'5" tall. So, it's not reasonable for me to have a goal as a center for the New York Knicks basketball team. But, gymnasts are generally about my size. So, being an Olympic gymnast might be a reasonable goal for me (when I was younger — much younger — that is). Most academic or business goals are usually less restrictive. There are a lot more doctors, lawyers, and engineers than there are professional athletes. For most people, it's usually easier to learn how to be a better doctor or engineer than it is to learn how to rebound better.

This leads to one of my favorite sayings which is, "Anyone can be anything they want, but no one can be everything they want." What I mean is that is that anyone can exceed well beyond what they think they are capable of. (If they work at it.) So, lofty goals are not unreasonable. You *can* be a senator or the vice president of a large company.

It's also important that your main goals in life be flexible and open-ended. Athletes often have problems because they don't see past the Super Bowl or World Series. How do you deal with a career that ends at age 27?

These are very competitive people who can no longer compete. They have no more goals in life. If they don't make new ones, they can have serious problems.

After you make a million dollars, will you stop? If you do, what do you plan to do after that? If you don't stop, how many millions do you want? (Making a million dollars is fairly straightforward — more on that later.)

I was talking to a business friend. She seemed serious when she said she wanted to retire and live the rest of her life in the sun on a beach. I asked her how long she really thought she could do that before she went nuts from boredom. She paused and said, "You're right. Probably a month." Do your goals fit you? That's important, too.

Engineers are very fortunate in that they often choose learning as a life goal. This is a great choice. It's open-ended. You can never learn

too much. And, it's flexible. Engineering is always changing. So, there are always opportunities to learn different things. And since engineers are pretty good at learning, there's no reason to limit your studies to engineering. A surprising number of older engineers like to take up completely different pursuits like music, art, or photography.

This discussion may seem off the point. How does this help you get that promotion? What I'm trying to show is that goal setting is part of human nature. We do it all the time, but often don't realize that's what we're doing. When we say we want something, we are setting a goal. It's important to have specific goals so that you can direct your energy in the most efficient manner. Success is about competing and winning. Not everyone will win.

Note, some people don't want to compete. They are happy to just do their job and get their paycheck. There's nothing wrong with this. Their lifestyle is just vanilla. This laid-back approach is a form of success, too. They have what they want. They've reached their goal. Remember, your success is what you think it is. Successful people are satisfied with themselves and satisfied with their life.

Paying for it

Would you rather be rich or happy? An interesting recent poll showed that Americans tend to choose "happy" while Asians tend to choose "rich". You have to decide the worth of your goal. How important is that raise or promotion? Are you willing to work an extra 10 hours a week?

You can see that determining what it costs to achieve a goal is closely linked to your plan. We'll look at them separately, but realize that there are trade-offs between them. In fact, it's very common and reasonable to change a goal once you realize what it will cost. (You can be a "B" student with a social life or an "A"

student without one.) Your cost is usually measured in work, risk, money, and sacrifice. Being an "A" student costs mostly work. You spend time on a lot of all-nighters to ace those exams. Being a poet, musician, or writer is risky. Your success depends on others appreciating your work. Money is often a component in success. It costs more to get into a major university than a community college.

Obviously, you'll have a better chance at success with a business degree from Yale than from Whatsamatta U. Sacrifice is a generic term. This refers to the intangible things you have to give up to pursue a goal, for example, less time with family and friends, a small TV instead of a big plasma screen on your wall, or, often, ridicule. This is because successful people tend to be independent, driven, and self-confident. This can be seen by others as unconventional, narrow-minded, and arrogant.

Psychology of Success and Failure

From my experience, there are two types of successful people. The first I call "gifted". These are people who have been marked as being successful from an early point in their life. They've always been supported by their parents, teachers, professors, coaches, etc. They are expected to always do well by themselves and with others. They go to special schools, have special classes, and are treated in a preferential way. They never fail.

I say "never" because, if they do fail at something significant, they tend to have a very hard time with it. Failure is not something they understand. They are hurt, angered, and bewildered by failure. Sometimes they never recover from a single big failure. I'm sure you've heard an announcer say, "If they pull that young quarterback now, he'll never get his confidence back." These people tend to have a strong but brittle ego. Like Humpty Dumpty, once it's broken, it's hard to put it back together.

The other successful type I call "relentless". These are self-driven people who have had no support group. These people tend to be extremely self-reliant and self-confident. They view failure as a challenge. They use failure as a learning tool. These people just never stop. The old saying "Nine times down and ten times up," is their motto. Or perhaps, "Never make the same mistake twice."

Most of us probably don't fit into the "gifted" group. But you don't have to be gifted to be "relentless". You can learn this. Realize that fail-

ure is an opportunity to learn something new. For "relentless" people, the only real failure is giving up.

Make a Plan

How you reach a goal can be easy or complicated, creative or conventional, fast or slow. It's up to you. Here are two plans to make $1,000,000.00.

The first way is to take a second job that brings in $200.00 per week after taxes (or set aside $200.00 per week from your regular job, if you make a lot of money.) Deposit this $200.00 in an account that provides seven percent interest. In 30 years, you'll have your million. Then you can retire and collect $70,000.00 per year, forever, from interest. This approach is mathematically guaranteed to succeed.

Another method (which I *don't* endorse or recommend), is to go to the art museum and steal the most expensive item and sell it for $1,000,000.00. Obviously, this carries a great risk of being locked up for 10 to 20 years — maybe with time off for good behavior. It's also socially unacceptable, difficult to accomplish, and simply rude. And, while the movies may glamorize art thieves and cat burglars, real criminals are not like the movies. Besides, what would your parents think?

These two plans are not acceptable to most people. Working 80 hours a week for 30 years is simply too long to endure. Being a criminal is also not something most people want. Obviously, a plan needs to fit you and your lifestyle.

Plans should be flexible, too. This is for two reasons. The first is that any plan may have problems. For example, you have an important job interview in the morning at 9:00 AM. The commute takes 30 minutes so you plan to leave at 8:00. By adding a half-hour, you will have the option to take an alternate route if your planned route is too congested. (Note that even this small success has goal, plan, cost, and execution phases.)

The second reason for flexible plans is that goals change. For example, say that you are working hard for a promotion. Then you find out that the company is on shaky financial ground. Your goal changes from getting a promotion to not being let go. Hopefully, your plan can be modified for the new goal.

Execute the Plan

This is usually the hardest step. Most people fail here for the simple reason that it takes effort. Here is where you pay for your goal. TANSTAAFL! There Ain't No Such Thing As A Free Lunch (Robert

Heinlein). No one is going to give you success except yourself. Dieters are the classic example of failing to execute a plan. The goal is to lose 10 pounds in a month. The plan is to go to the gym twice a week and to eat less. The cost is time and no more chocolate. But, I'm too busy this week to go to the gym. And I went out for lunch and they had a birthday party and I couldn't refuse the cake. And then there's your mother. "You're not going to get that A if you don't study!" She knows all about executing a plan.

Competition

In some things, you can be successful all by yourself. You can learn a new computer language by yourself, or ride a bicycle, or design a circuit. There are other times when you have to compete with others to be successful. Obviously, you can't win a tennis match without beating your opponent. And lots of others want that trophy, job, or promotion just as badly as you do. The first thing to realize is that competing against others is always uncertain. The simple and obvious reason is "success" now depends on what others think and do. Your boss chooses who is "successful". Your co-workers may have advantages you are not aware of. This type of success cannot be controlled by you. However, you can certainly influence and enhance your chance of winning by following the four steps of success.

Getting that New Job or Promotion

What is your real goal here? Do you want more money? Do you want the prestige of a nice title? Do you want to have a more interesting job? If you don't know exactly what you want, you can't plan for it. When competing, the planning stage is usually second followed by the cost of implementing the plan. And in order to make any plan, you have to have information. What are the others' qualifications and abilities? What are your strong points? More importantly, what are your weak points? What are the standards you will be measured on? If you don't know these things, you will have little chance of success. If you are competing for a new job in a new company, learn everything you can about the company. Learn how it was founded, who runs it now, their work ethic, what they do, why they do it, how big it is, etc. With all the websites nowadays, this is easier than ever. The most critical piece of information you need is to learn exactly what *they* want. Or, more to our point, what is their goal? They want to succeed, too. They have a goal, plan, and cost already in place. Now they are executing that plan. You need to match your plan to their goal better than anyone else. Then you have to make them aware of that.

For example, a long time ago, I wanted to work at a particular company. I researched them and determined what mainframe computer system they were using. I then called the local representative of that computer system to get some details about the system in general. I had a nice conversation with the representative and he mentioned that the company had just ordered a new system. At the interview, I was asked if I was familiar with the computer type they were using. I said yes but that it would be interesting to learn about their new system. You know, the one you ordered a few weeks ago. The interviewers looked at each other with their mouths open. The goal of most interviewers is to find aggressive, hard-working, and competent people. Those two sentences clearly demonstrated that to them. I should point out that these people wanted to hire me on the spot. However, another interviewer felt I "looked too young." I was later told that there was quite a battle between the interviewers. I did not get that job. This points out the fact that no one can plan for everything. Plans fail for reasons you might never consider. But, the failure of the plan does not mean that the person is a failure. It's important to know this. Of course, it's disappointing and discouraging. It's not personal, though.

Cheating

Success through unethical behavior is a topic that clearly has to be discussed. Some students cheat to get a better grade. Athletes sometimes use drugs to enhance their performance. Executives may take money from

stockholders by manipulating the books. Some politicians lie to get votes. Sometimes it seems that there are no honest people. Cheating is part of the "cost" of success. Are you willing to risk your reputation? Your health? Your freedom? How important is success to you? Fundamentally, it makes little sense to risk something big to get something small. Cheaters view success as being the most important thing. Or perhaps, failure as the most unacceptable thing. It is really just a matter of values. Cheaters usually have low self-esteem.

No one can judge another person's values. And society places ethics and success in conflict. It's human nature to want to win. It's also human nature to be fair. This is just because we are social beings and have empathy with others. What is right and wrong changes as society changes. But, it's never been right to take advantage of others (but it's done on a regular basis, anyway). Whatever decisions you make concerning ethics, you will be bound by them. The saying that "nice guys finish last" does have some truth. On the other hand, there is usually a great satisfaction in seeing the bad guy get what he deserves. And, if you do cheat, and someone finds out, you've just given that person power over you. Did you factor that into your cost?

Success as a Habit

Success breeds success. Why? Actually, there are two basic reasons for this. The first is that success builds self-confidence. That's because there is always risk associated with success. This is the "cost" part. If you risk something and succeed, you are more willing to try again. The second point is that you learn what works. Failures show what doesn't work. Obviously, it's easier to learn from what does work than what doesn't. (Although, sometimes it's extremely important to know what doesn't work.) One other point: if you like doing something, you will be much more likely to succeed. It's synergistic. You like it, so you do well. You do well, so you like it more. If you can find a career doing something you like, your chances of success are greatly enhanced. There's the old story about Babe Ruth's first professional baseball contract. Ruth was told, "It's $100.00 per game." The Babe sadly replied: "I can't pay you that much."

Conclusion

The road to success is basically a four-step process. If you are aware of the steps, you will have a better chance to succeed. Once you learn to succeed you will find that it is very possible to achieve much more than you ever thought possible.

And regardless of what anyone else thinks or says, if *you* think you have reached your goals, then you are successful. **NV**

Tech Forum

QUESTIONS

Does anyone have a schematic for a well-regulated and efficient (little wasted energy) 120 VAC transformerless power supply (no step-down transformer of any kind — just diodes, resistors, caps, and voltage regulators) with an output of 9 or 12 VDC at 40 mA?

#2041 **Joe**
via Internet

We are searching for a solution to the problem of the ultrabass sound from stereos in cars that drive down the busy street we live on. The loud bass noises and vibrations penetrate our house, setting off resonances that rattle our walls and windows. The rumbling from other vehicles — buses, trucks, and trains — is also an aggravation.

Is there a technology available, or one that could be easily developed, that could cancel out these noises? Or, perhaps, is there a metal screen that could be plastered into the walls and have applied to it a charge that would cancel out the low frequency sound waves, similar to the screen embedded in the glass of the microwave oven door?

We would appreciate help with this problem, which is becoming more persistent.

#2042 **Melvin Pedersen**
via Internet

I noticed that your magazine is for the beginner, as well as the professional. Where does someone start who is interested in electronics? I checked with a local school, but they wanted thousands of dollars in tuition costs. I would appreciate any information you can provide.

#2043 **Lodrick Price**
via Internet

I have several USB flash memory sticks that I like to use simultaneously. Most USB "hubs" have the (typically, four) receptacles so close that, at best, I can get three USB sticks in, and sometimes only two. What I need are some short (preferably about eight inches or less) USB extension cables, but the shortest I've seen are three feet and the "retractable" USB cables are typically very pricey ($12.00+). Does anyone know either of a source for short USB cables or a source for USB cable connectors to allow me to roll my own?

#2044 **Larry Supremo**
via Internet

I'm looking for a composite video level generator that sweeps from black to white, to simulate the output of an iris control circuit in a video camera. Any assistance would be greatly appreciated.

#2045 **Roy Bock**
via Internet

I have a standard personal computer that has serial inputs. Is there an adaptor I can build, or purchase, to add USB ports to my machine?

#2046 **Ken Johnson W9BIH**
Dixon, MO

I need to generate a 0- to 5-volt triangle wave. I tried to obtain this from a 555 timer chip, but it only produced a waveform that varied from 1/3 to 2/3 Vcc. Can anyone help me out with a circuit?

#2047 **Huseyin Akgul**
Ankara/Turkey

The last two batteries on my Compaq Armada M300 notebook have died and replacements are wickedly expensive. A simple alternative would be to supply an external 18.5 V at 2.5 A, with some

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This is a READER-TO-READER Column. All questions AND answers will be provided by *Nuts & Volts* readers and are intended to promote the exchange of ideas and provide assistance for solving problems of a technical nature. All questions submitted are subject to editing and will be published on a space available basis if deemed suitable to the publisher. All answers are submitted by readers and NO GUARANTEES WHATSOEVER are made by the publisher. The implementation of any answer printed in this column may require varying degrees of technical experience and should only be attempted by qualified individuals. Always use common sense and good judgement!

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ANSWER INFO
- Include the question number that appears directly below the question you are responding to.
- Payment of $25.00 will be sent if your answer is printed. Be sure to include your mailing address if responding by email or we can not send payment.
- Your name, city, and state, will be printed in the magazine, unless you notify us otherwise. If you want your email address printed also, indicate to that effect.
- Comments regarding answers printed in this column may be printed in the Reader Feedback section if space allows.

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To be considered
All questions should relate to one or more of the following:
1) Circuit Design
2) Electronic Theory
3) Problem Solving
4) Other Similar Topics

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- No questions will be accepted that offer equipment for sale or equipment wanted to buy.
- Selected questions will be printed one time on a space available basis.
- Questions may be subject to editing.

Helpful Hints
- Be brief but include all pertinent information. If no one knows what you're asking, you won't get any response (and we probably won't print it either).
- Write legibly (or type). If we can't read it, we'll throw it away.
- Include your Name, Address, Phone Number, and Email. Only your name, city, and state will be published with the question, but we may need to contact you.

sort of voltage converter using a 12 V gel cell. Does anyone know of a simple circuit for accomplishing this?

#2048 **Mark Warner**
via Internet

I am an electronics teacher hunting for electronics jokes to use in class. The cornier the better! I am already using the "mobile ohm" and "ohm ohm on the range," to give you an idea of what is working.

#2049 **Dave Brett**
via Internet

(Bring 'em on! — Editor Dan)

I have a surplus VFD display module that I'd like to use in a club project, but it has no specs. It looks like one of those large cash register displays that's mounted on a pole. Inside is a pair of Futaba M202LD01DA vacuum fluorescent displays. The interface cable has eight pins where 20 VDC power is applied and an RS-485 serial interface is used to talk to the modules. Futaba was unable to help, can anyone else?

#20410 **Kelly Small**
Phoenix, AZ

I am about to purchase a DVD recorder/player; however, there are so many supported formats that I need help understanding the differences. A sales person at a consumer electronics outlet told me there were three formats — plus, minus, and progressive — but could not describe any of them. I know what progressive scan is, but what about the other two? I do not understand how a disc recorded in progressive scan can be played back on an interlaced monitor. Can anyone direct me to a source that can give me the facts without trying to sell me something?

#20411 **E.A. Hill**
via Internet

I would like to build an engine governor for my R/C helicopter, using a set of points and the existing throttle servo. I have been experimenting with 555 ICs as the timing device. Does anyone know of a circuit I could use?

#20412 **Dean Nicholas**
via Internet

Does anyone have a simple circuit to test for continuity up to a few hundred ohms? I know these are built into most digital voltmeters, but I want a small, knock-around unit.

Michael Herman

(Read TJ Byer's column in the January issue — Editor Dan)

ANSWERS

[11038 - November 2003]

I have some Gateway 2000 4DX-66V computers that have a BIOS password that prevents them from booting. Is there a master password that I can use to get in?

#1 Generally, there is not a master password. There is, however, an alternate solution. You need to force the system to forget that it is password protected. This is done by generating an invalid checksum to force erase the CMOS RAM. Either remove the backup battery or find the jumper on the motherboard that enables power to the CMOS memory and remove it. It will be physically close to the battery and the CMOS.

Some motherboards have a three pin header. The center pin is common. The outer pins are normal operation and erase. Move the header from one side to the other. It may take several minutes if you are just disconnecting the battery. The computer should return to the factory default, with no password protection. When done, replace the battery or jumper, so that the computer can remember other settings, such as hard disk type and time.

Barry Cole
Camas, WA

#2 There are zillions of sites where you can download software for BIOS password recovery, such as **www.cgsecurity.org**

Olli
Finland

#3 The easiest way to access a password-protected BIOS setup is to remove the backup battery for a few minutes. This will reset all of the CMOS settings, including the password. You will then be able to access the BIOS, but you will also need to reset all of the hardware settings, such as the hard drive type and floppy drive configuration.

Backup batteries vary by motherboard vintage. Older motherboards have an external battery pack, which is connected to the motherboard by a header. Just remove the header for a bit and then replace it. Newer motherboards use a

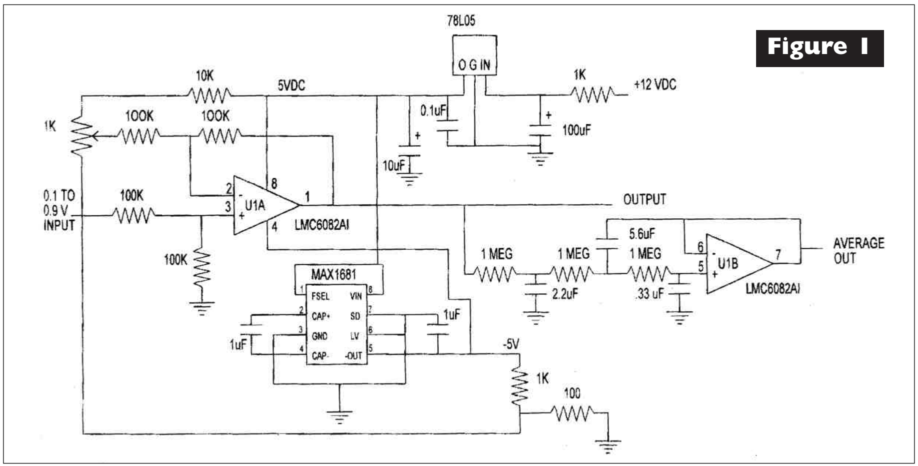


Figure 1

coin cell that can easily be popped out of its holder. Some, quite possibly yours, will have a three-cell battery which is soldered in place near the edge of the motherboard. If this is the case, then look for a small header with three pins and a shorting plug near the battery. Moving the shorting plug to the opposite set of pins will disconnect the battery from the CMOS backup memory. In all cases, be sure that the power to the computer is off, otherwise the backup memory will be powered from the main supply and disconnecting it will have no effect.

David Sarraf
Elizabethtown, PA

[110310 - November 2003]

I need a circuit that will track a changing voltage (+0.1 to +0.9 V) and allow me to use a potentiometer to create an offset of ± 0 to 3 millivolts and adjust to an average of 0.45 V. This circuit is to track the output of an automotive O2 sensor.

In this circuit (Figure 1), the LM78L05 provides isolation from the noise on the 12 V supply. The U1A amplifier circuit has unity gain for the input signal and the ±5 volts that is available at the pot. You should use 1% resistors for accurate results. The MAX1681 is a +5 to -5 inverter; use film or ceramic 1 mF caps. Since the LMC6082 is a dual, I used the second op-amp in a low-pass filter so the average voltage can be measured. The capacitors should be film type for accurate results. The internal offset of the op-amp is less than 1 mV, so I assumed that was neglectable.

Russell Kincaid
Milford, NH

[11037 - November 2003]

Does anyone know of a simple data logger I can use to record the time and date of each instance a switch is turned on and off and keep it in memory?

The H06-001-02 Hobo™ Data Loggers from Onset will record up to 2,000 different changes (on/off) and the time each happens. They require the BoxCar 3.7 (BC3.7-DL) software to download the information. This system was very user-friendly for me. Both should be at **www.digikey.com**

Brian German
via Internet

[12031 - December 2003]

What is the difference between an S-video input and the plain old video input on a television set?

An S-video cable is a higher grade of the plain old composite video input. The difference between the two is that S-video provides more bandwidth to the TV set. There are basicially two feeds coming in at once, chrominance and luminance (or color and brightness) and that's why there are four pins.

When using S-video, there is better picture quality. To put it in easiest terms, a data path for color and a path for brightness — where composite video has to accomodate for both and the picture sometimes looks "washed out".

Video quality for home users is, from best to worst: fiber, component (RGB), S-video, composite video, and RF (audio and video AKA cable feed).

Shon Kelly
Ontario, Canada

[110311 - November 2003]

I want to build a current

sensing switch to turn on an audio amp when my television is switched on by remote. I want a pass-though type sensor so as not to break the power circuit of the device being monitored.

#1 In the circuit in Figure 2, you will have to break the line in order to run one of the AC wires through the current transformer, but there will be no voltage drop due to the current measurement. The transformer is rated for 5 A. You will need a 50 A transformer for the hot water heater. The diode at the op-amp input prevents negative voltage from damaging it. The diode at the op-amp output rectifies the signal and produces the voltage to operate the relay. The 1 M resistor ensures that the relay switch opens when the television is turned off. The NPN transistor is its own protection against the inductive kick of the relay coil, so no diode is needed.

Russell Kincaid
Milford, NH

#2 I'm doing exactly this with the Craftsman Auto Switch, Sears item #00924031000 (**www.sears.com**). It has one master (sense) outlet and two slave outlets.

It's marketed as a shop tool, to do things like turn on a work light and a shop vac on the slave outlets when a table saw is powered up on the master outlet.

Best of all, it's only $19.99! It would be hard to purchase the project parts for less than that.

Wil Higdon
via Internet

[12036 - December 2003]

I'm building a three axis robot arm using stepper motors, controlled through the parallel port of a PC. I'm having difficulty building the controller board, and writing the software to run it.

Can anyone point me to any good information?

There are many excellent sources on the Internet that can show you various ways to control a stepper. If you are looking for a place to start which emphasizes the basics, I can suggest my site: **www.taomc.com** (The Art Of Motion Control).

I have tried to distill the process of using the PC printer port and inexpensive components to create fun and instructive stepper-based projects.

Over the past four years in the education department at the Science Museum of Minnesota, I have taught a class which has included kids as young as 12. The course, "From Bits to Bytes to Bots," showed how to build, wire up, and then control a two-axis spherical plotter ("Eggbot").

The site contains several examples of do-it-yourself, PC-based motion control. The specific area which contains detailed explanations (including breadboard diagrams and QBASIC examples) is: **www.taomc.com/bits2bots/**

Bruce Shapiro
Edina, MN

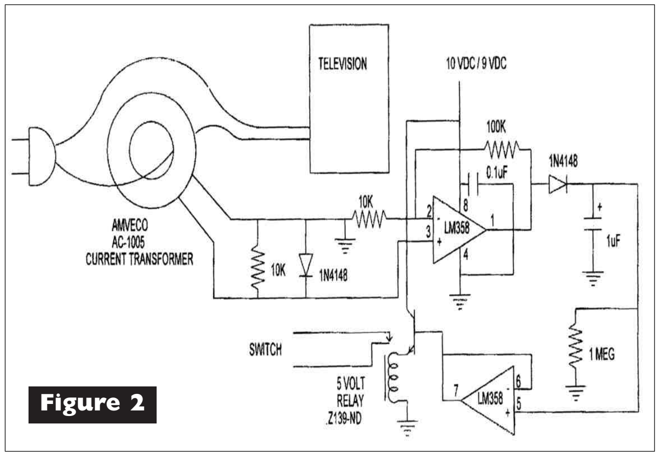


Figure 2

[12037 - December 2003]

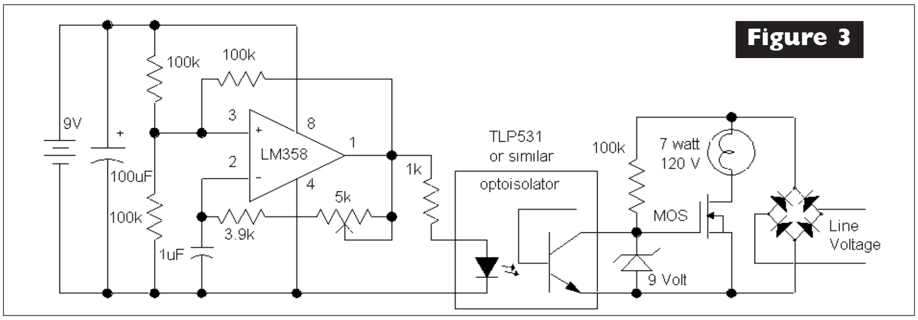
Does anyone know of a reference book on electronic component footprints?

If you mean footprints for a PCB package, the IPC Land calculator is great (see **http://landpatterns.ipc.org**). It includes a bunch of footprints for various packages and if you input the parameters of the package you are using, it will tell you what the PCB footprint should be.

Colin O'Flynn
Ontario, Canada

[1042 - January 2004]

I would like to light a crystal from underneath with lights that slowly illuminate and fade to produce different colors. I have made a couple different circuits



using blue, red, and green LEDs and triangle wave circuits, but they are not as bright as I'd like.

Any suggestions out there?

#1 Go to **www.BGMicro.com** or **www.Goldmine-elec.com** as both offer an integrated three-color LED in a T 1 3/4 package with an internal controller chip that does exactly what you want, for less than $3.00. They are bright enough to light a tennis ball-sized crystal in a dark room. Just apply 4 VDC at 20 mA and you are all done. Use several for a more complicated display.

David D. Speck MD
Auburn, NY

#2 I really like that idea — so I had to build one! Instead of using a slow triangle wave, I used a square wave near, but not exactly at, the line frequency to turn an AC lamp on and off (see Figure 3). When the 120 Hz square wave from the op-amp is high, it turns on the high voltage power MOSFET (just about any will work) and the lamp sees the voltage from the bridge. If the line voltage happens to be high, the lamp is bright, but if it is more near zero volts, the lamp is dim. As the square wave drifts relative to the line voltage, the brightness goes up and down.

Originally, I used 60 Hz and a half-wave rectifier, but the lamp was off too much of the time. Moving to 120 Hz and a full-wave rectifier keeps the lamp partially lit at all times. Simply adjust the potentiometer until the lamp is changing at the desired rate. Use a non-polar 1 µF capacitor op-amp and a good multi-turn pot to set the frequency. The optoisolator is not critical, as long as it can turn the MOSFET completely on and off. The full-wave bridge can be a molded type or just four diodes rated for AC line voltage. Make sure to use a fuse, too.

A quad op-amp could run four lamps and the nine-volt battery could be a molded power supply or the line voltage can be dropped down with a power resistor and zener, but remember that the op-amp circuit then becomes a shock hazard, too.

Charles Wenzel
Austin, TX

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